A COMPARATIVE STUDY OF WATER QUALITY CONSTITUENTS AND PHYSICAL PARAMETERS IN SKIATOOK LAKE FOR 1993, 2003, & 2004

By

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A COMPARATIVE STUDY OF WATER QUALITY

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IN SKIATOOK LAKE FOR 1994, 2003, 2004

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CHAPTER I

INTRODUCTION

Skiatook Lake is located in Osage County, northeastern Oklahoma. The lake was constructed by the Corps of Engineers to provide flood control, water supply, and water quality control. It also provides fish and wildlife habitat (U.S. Army Corps of Engineers). Skiatook Lake offers lots of opportunities to the public for recreational activities and is valued for its aesthetics. It has become popular due to its location near several large cities and its quality of water and has become an established location for family activities. This paper analyzes water quality parameters to see if there have been any significant changes in the past decade.

Nutrients can enter surface water by means of runoff throughout the watershed. Runoff can occur due to anthropogenic and non-anthropogenic activities. Since impoundment, land within the watershed has been used for residential and commercial development, ranching, and oil production. Surfaces such as parking lots, roads, and other concreted areas are impervious surfaces. Impervious surfaces allow runoff to reach the lake faster than non-paved areas. These areas also take away from the natural buffer zones which help absorb pollutants. Skiatook Lake has 8 recreational parks. They consist of 2 marinas, 8 boat ramps, 7 docks, 3 camping areas, and 8 public restrooms (Figure 1). Some other anthropogenic activities that can contribute include: prescribed burning, land development, and any type of vegetation clearing. Many ranches do prescribed burns each year in the spring, temporarily clearing the land of vegetation. Runoff from fertilized fields or cattle ranches can also increases nitrogen and phosphorus concentrations. Major natural environmental changes such as fires, floods, and climate change will increase nutrient concentrations in surface water as well.

Figure 1. Map of Skiatook Lake Including all the Recreational Facilities. Source: http://www.skiatook.com/skiatook/images/skiatooklake.jpg

This paper focuses on total phosphorus and total Kjeldahl nitrogen shifts, whether positive or negative, that had occurred from 1994 to 2004. It also includes turbidity and Secchi disk readings to analyze water clarity. Chlorophyll a is explored for the years 2003 and 2004. Sediment will affect water visually; the most obvious effect is increasing turbidity (Grobler et al.

1987). Phosphorus will attach to suspended sediment in the water column, so turbidity can be used as a surrogate for the estimation of total phosphorus (Jones et al. 2011). Phosphorus is a common cause for surface water impairment. If there is a decrease in water quality, management practices may need to be implemented.

CHAPTER II

REVIEW OF LITERATURE

Location Description

Skiatook Lake is located in Osage County, Oklahoma and is a part of the Bird Creek watershed (EPA). It is located within the Crosstimbers region. The Crosstimbers region is defined as an area that transitions the Tall Grass Prairie to the mountains of southeastern Oklahoma (OCS). It is an area filled with rolling hills, open blackjack (*Quercus marilandica)* and post oak (*Quercus stellate*) woodlands, interspersed with grassy savannah areas (Abbot and Tortorelli 2002). Land within the watershed is primarily used for farming, ranching, and oil and gas production (Krantz-Smith and Zerby).

Skiatook dam was approved October 23, 1962 for construction (U.S. Army Corps of Engineers). Land acquisition began in 1973 and construction began in 1974 (U.S. Army Corps of Engineers). This reservoir was created as a flood-control impoundment for Hominy Creek by the U.S. Army Corps of Engineers and was completed in 1984 (Long and Fisher 2006). They constructed an earth embankment dam, a gate tower, outlet works, project building, an overlook structure, and public facilities (Krantz-Smith and Zerby). Elevation of the top of the dam is 756 feet above sea level (U.S. Army Corps of Engineers).

The main tributaries for this lake are Hominy, Turkey, Tall Chief, Sand, Mahala, Gouin, Bull, Wildhorse, and Boar Creeks (Krantz-Smith and Zerby). The hydrology of Skiatook is less variable than most other reservoirs located in southeastern U.S. was 2.9 meters with the largest fluctuation being 4.2 meters (Long 2000). Skiatook Lake is 4,226 hectares with a mean depth of about 9.7 meters (Long and Fisher 2006). It has a shoreline development index of 11.3 (Long and Fisher 2006). Shorelines around the lake largely consist of steep bedrock substrata with little aquatic vegetation (Long and Fisher 2006). Skiatook Lake serves as a flood control, a water supply, recreational area, and a fish and wildlife management area (U.S. Army Corps of Engineers). Total costs of the project were approximately $120 million (U.S. Army Corps of Engineers).

Climate

Skiatook Lake is located in an area with long summers and moderate winters (Alexander Consulting Inc. 2003). The climate here is very diverse and will change from one extreme to the other, within a 24 hour period. Yearly average temperature is approximately 59 degrees Fahrenheit, but temperatures have ranged from negative 26 to plus 118 degrees (Alexander Consulting Inc. 2003). Average yearly highs occur in July and August is approximately 93 degrees Fahrenheit. The lows occur in January and average out to approximately 23 degrees Fahrenheit (OCS).

Between 1971 and 2000, Osage County received an average annual precipitation from about 36 inches to 45 inches (OCS). More rain falls on the east side of the county than the west. Rainfall in the summer usually comes in short durations, but intense amounts; whereas during the winter rain falls in low intensities, over a larger area for several days (Alexander Consulting Inc. 2003). On average, May and September are the wettest months for this area (OCS). April through September is the growing season when nearly 2/3 of the precipitation occurs (Alexander Consulting Inc. 2003). Figures 1 and 2 are graphs depicting annual and monthly precipitation for the years of 1994, 2003, and 2004; concurrent with the sampling years in this project.

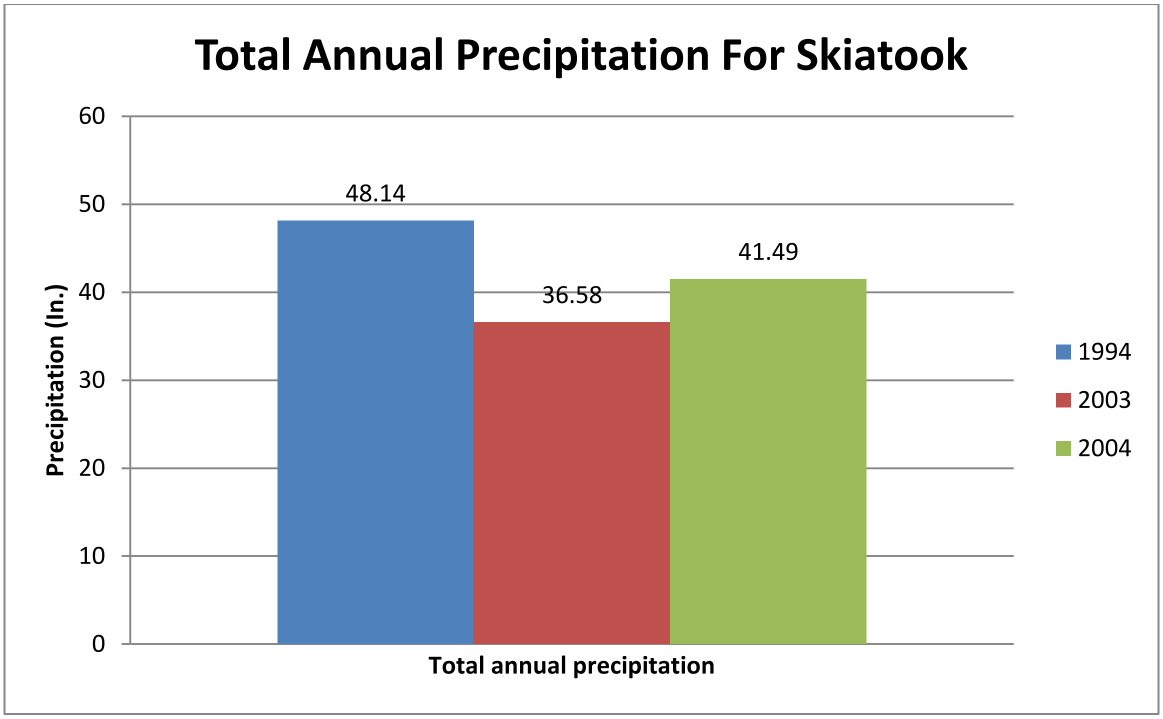

Figure 2. Total annual precipitation for Skiatook during the 1994, 2003, and 2004 sampling period.

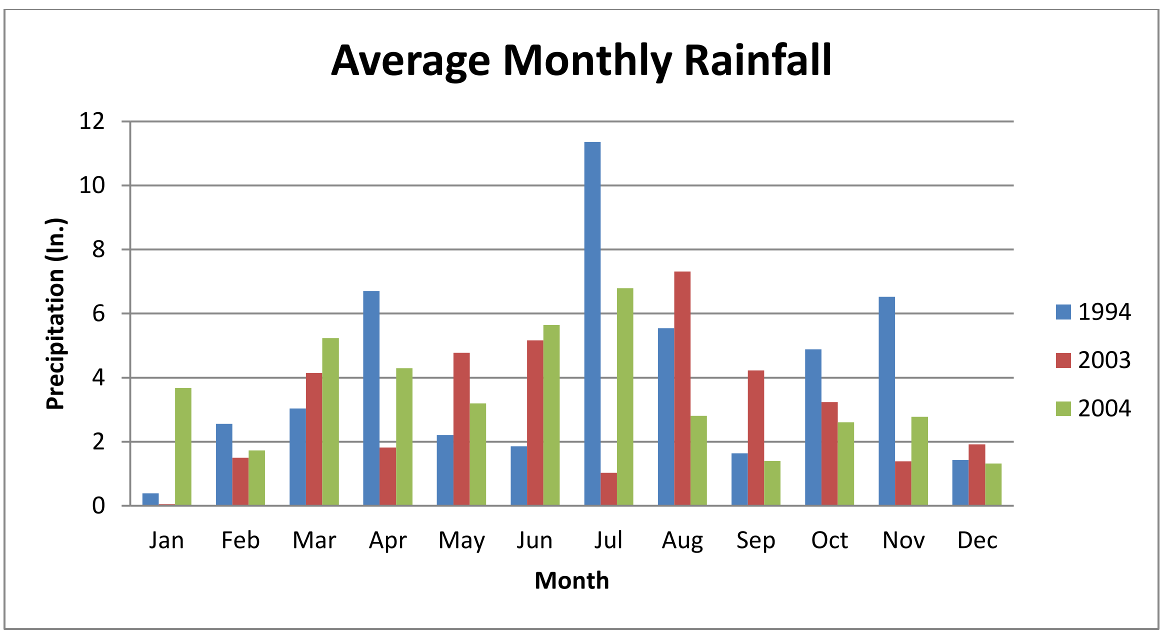

Figure 3. Average monthly rainfall for Skiatook during the 1994, 2003, and 2004 sampling period.

Soils

Land around Skiatook Lake is composed of several different kinds of soils; the predominant type in the area is the Niotaze-Darnell complex (Alexander Consulting Inc. 2003). This type of soil forms on the crests and side slopes of uplands (Alexander Consulting Inc. 2003). It is a mixture between well drained to poorly drained soils. It's deep in some areas and thin in others (Alexander Consulting Inc. 2003). Niotaze soils, deep and poorly drained soils, compose approximately 65% of the adjacent land surrounding the lake (Alexander Consulting Inc. 2003). This soil is composed of dark grayish brown silt loam with an upper part that is reddish brown silty clay. Underneath this is shale bedrock. Permeability of this soil is slow (Alexander Consulting Inc. 2003). Darnell soil makes up from 15 to 35%. It is dark grayish brown fine sandy loam with sandstone bedrock underneath it. Permeability of this soil is moderately rapid with low water capacity (Alexander Consulting Inc. 2003).

Water Quality

Terrestrial runoff within the watershed and atmospheric input are primary sources of new nutrients entering a lake (Guildford and Hecky 2000). The amount of inputs can vary from one location to another (Guildford and Hecky 2000). Inlet waters are directly impacted by availability of nutrient runoff and the overall effect can impact the lake (Fillos and Swanson 1975). Increasing levels of nutrients entering the lake can shift a reservoir's trophic level from a lower level to a higher one (Alexander Consulting Inc. 2003). Oligotrophic lakes have low nutrient levels and therefore lower productivity. This type of lake has clear water with little turbidity. Mesotrophic lakes are an intermediate trophic level. Eutrophic lakes are high in nutrients and highly productive, but show a reduction in aesthetics (Alexander Consulting Inc. 2003). Regardless, eutrophic lakes can be productive warm water fisheries, but may have low aesthetic values (Alexander Consulting Inc. 2003). R. E. Carlson developed the trophic state index (TSI) formula to describe a lakes trophic state (Shelley et al. 2005). The TSI takes into account Secchi depth, chlorophyll concentrations, and total phosphorus (Shelley et al. 2005).

TSI Calculations have been reported for Skiatook Lake by the Oklahoma Water Resources Board (OWRB) in their annual beneficial use monitoring program (BUMP) report since 2000. During 2000, the TSI was calculated for Skiatook Lake using the Carlson's index. The lake was classified as mesotrophic with a TSI value of 49 then, and in 2003-2004 it was still classified as mesotrophic with an average value of 45 (Oklahoma Water Resources Board 2001 and 2004). Mesotrophic lakes generally have moderate levels of productivity and moderate nutrient conditions (Oklahoma Water Resources Board 2004). TSI was calculated for each season, all of which differed from one another. During the fall and winter, the values were mesotrophic; during the spring and summer, the values were split between oligotrophic and mesotrophic (Oklahoma Water Resources Board 2004).

A total maximum daily load (TMDL) is the maximum allowable amount of specific pollutants that a waterbody can assimilate and still meet its designated uses (EPA). If the waterbody can't be utilized for its designated uses, it is defined as impaired (Shelley et al. 2005). TMDLs allow states to have a target amount and provide data to help manage the lakes. Every state must submit a list of its surface waters that exceed their water quality standard limits; this is required by the Clean Water Act, section 303(d) (Shelley et al. 2005). Skiatook Lake had no cause of impairment for the study period of 1994 through 2004 and is in need of a TMDL (EPA).

Salinity, Specific Conductance, pH, and Dissolved Oxygen

The OWRB recorded values for salinity, specific conductance, pH, and dissolved oxygen during 2003 and up for the remainder of the water characteristics. Salinity was within the normal average for Oklahoma and ranged from 0.09 parts per thousand (ppt) to 0.23 ppt (Oklahoma Water Resources Board 2004). Specific conductance ranged from 197.6 to 282.4 mS/cm

(Oklahoma Water Resources Board 2004). The pH ranged from 6.59 to 8.18 which are neutral to slightly alkaline (Oklahoma Water Resources Board 2004). Dissolved oxygen levels were reported to be a threat in 2000 (Oklahoma Water Resources Board 2001). In the 2003 sampling year, the spring and winter the lake dissolved oxygen was well mixed, not stratified (Oklahoma Water Resources Board 2004). Thermal stratification occurred during the summer and fall (Oklahoma Water Resources Board 2004).

Secchi Disk and Turbidity

Higher phosphorus levels in surface water is associated with lower Secchi disk readings. One reason that may account for this is that chlorophyll a levels raise when phosphorus levels rise (Oklahoma Water Resources Board 2004). There are studies indicating that turbidity can be linked to phosphorus levels. In some cases turbidity is used as a surrogate for phosphorus measurements (Jones et al. 2011). Shifts tend to occur rather abruptly between a clear and turbid state. Some shallow lakes never recover, back to their original clear state, even after nutrient loads have been decreased (Scheffer and van Nes 2007).

According to the BUMP report, during the year 2003 the lake had an average turbidity of 13 NTU (Oklahoma Water Resources Board 2004). The true color was 34 units and the lake had an average Secchi disk depth of 137 centimeters (Oklahoma Water Resources Board 2004). It was concluded when analyzing these three parameters that the lake had excellent water clarity. The turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 for the year (Oklahoma Water Resources Board 2004). The only exceptions were in Bull and Hominy Creeks (Oklahoma Water Resources Board 2004). Overall, the OWRB concluded that the aesthetic beneficial use was fully supported in 2003 and 2004 (Oklahoma Water Resources Board 2004).

Phosphorus and Nitrogen

A driving source in ecosystem development and succession is nutrient limitation (Koerselman and Meuleman 1996). Phosphorus contributes to the regulation of algal and macrophyte growth in surface water (Shelley et al. 2005). It is used by organisms to store and transfer cell energy (Cole 1994). Phosphate is the most common form of phosphorus found in natural fresh waters (Shelley et al. 2005). It enters the aquatic environment in a number of different ways: atmospheric deposition, ground water percolation, runoff, municipal treatment plants, industries, and agricultural activities (Shelley et al. 2005). Nitrogen is found in four recognized spheres of the earth (Cole 1994). The lithosphere holds 93.75%, only 6.2% is atmospheric, and the remainder is tied up in the biosphere (Cole 1994). Once molecular nitrogen is dissolved into the soils, it can only be broken down by a select few organisms (Cole 1994). Nitrogen is the fourth most common element in living cells; nitrate is generally the most common form of inorganic nitrogen in lakes (Horne and Goldman 1994). Biological uptake of nitrate is higher in the spring and summer; therefore lowering concentrations in the photic zones (Horne and Goldman 1994). It is then replenished from sediment release, tributary inflows, and precipitation (Horne and Goldman 1994). This paper addresses total Kjeldahl nitrogen (TKN). TKN is the measurement of nitrate (NO_3) and nitrite (NO_2) combined (Shelley et al. 2005).

Nutrient concentration depends on the amount of nutrients available in the watershed and its potential mobility to the lake (Fraterrigo and Downing 2008). A watershed's hydrology, geology, soil type, and topography characteristics can influence nutrient transport (Fraterrigo and Downing 2008). Phosphorus can remain contained in surrounding soils and root zones (Dunn 2011). External loading into lake systems occurs more often in agricultural and industrial setting (Dunn 2011). Two main sources of nitrogen are effluent from municipal treatment plants and agricultural sites (Shelley et al. 2005).

Retention time of the water in lakes is also very important to nutrient loading because it will determine where dissolved and suspended particles are located within the water column (Dunn 2011). Large lakes seem to be less susceptible to pollution due to the dilution effect, but if the lake holds stagnant water for long periods of time, the pollution doesn't get flushed out (Cole 1994). So, stratified lakes are more susceptible to nutrient buildup than unstratified lakes (Cole 1994). The amount of time water is retained will have a direct impact on biological and chemical reactions that may occur (Dunn 2011). Hydrological inputs and outputs need to be considered when analyzing nutrient levels in lakes.

The OWRB collected water quality samples during 2003 and 2004 to analyzed total nitrogen (TN) and total phosphorus (TP) at the surface of the lake and at the bottom. These water quality parameters were not available in the BUMP report for the previous years. Surface levels of TN ranged from 0.13mg/L to 1.42 mg/L and were higher during spring (Oklahoma Water Resources Board 2004). Average levels lake-wide were 0.48mg/L at the surface and the average bottom level was 0.53 mg/L (Oklahoma Water Resources Board 2004). Surface levels of TP ranged from 0.005 mg/L to 0.111 mg/L (Oklahoma Water Resources Board 2004). Average levels lake-wide for TP were 0.016mg/L at the surface and 0.013 mg/L at the bottom of the lake (Oklahoma Water Resources Board 2004

The nitrogen to phosphorus ratio is used to define if the aquatic system is phosphorus deficient or nitrogen deficient. If the ratio is greater than 30, phosphorus is identified as the limiting nutrient; if the ratio is 10 or less, nitrogen is the limiting nutrient (Shelley et al. 2005). When the ratio falls between 10 and 30, then both are considered the limiting nutrient (Shelley et al. 2005). For the sample year 2002-2003, the OWRB calculated an N:P ratio for Skiatook Lake. The ratio was 31:1, characterizing the lake as phosphorus dependent. Sampling year 2004-2005 had a N:P ratio of 20:1 (Oklahoma Water Resources Board 2004).

Chlorophyll a

Chlorophyll a is an essential component found in plants and is used for converting light energy into chemical energy; a process called photosynthesis. During this process, chlorophyll transforms carbon dioxide and water into carbohydrates and oxygen (Shelley et al. 2005). There are many types of chlorophyll, but the most predominant one is chlorophyll a (Shelley et al. 2005). Increased amounts of chlorophyll a present, means there will be an increased amount of algae present. Algae are the primary producer in the aquatic food web and are used to characterize the productivity of surface water (Shelley et al. 2005). Changes in the structure of algal communities includes: large algae blooms that can then be followed by algal die-off. The depletion of the community is a result the depletion in dissolved oxygen concentrations (Shelley et al. 2005).

Nutrient limitation can affect the amount of competition between organisms and force adaptation to survive in lower nutrient levels (Koerselman and Meuleman 1996). Normally, biomass production can be enhanced by adding the specific limiting nutrient. Each species will have their own specific nutrient requirements, absorb it at different rates, and vary in their ability to use it (Gusewell et al. 2003). Trophic status is largely supported by the relationship between phosphorus and chlorophyll (Williamson et al. 1999). It has been stated that chlorophyll concentrations rise linearly with phosphorus concentrations (McCauley et al. 1989). The greater the concentration of phosphorus, the larger the concentration of chlorophyll a will be (Dunn 2011). Together these two play a large role in algal growth. Limiting nutrients, major ions, pH, and other physical factors all combined determines the reproductive rate of an algal population (Tilman et al. 1982). Unfortunately, data collected by the U.S. Army Corps of engineers didn't include samples of chlorophyll a for 1994.

CHAPTER III

METHODOLOGY

Data Collection

Water quality data used in this paper was collected by the U.S. Army Corps of Engineers. The raw data is available in appendix 1. Ten sites were sampled and data from these sites were combined analyzed together. In 1994, samples were collected from April to November. Samples were collected from March until October in 2003 and in 2004 they were collected from January through September. Only 4 of the 10 sites were sampled for all 3 years: 1994, 2003, and 2004. Sampling dates and stations sampled are listed in Appendix 1. Figure 3 depicts each sampling site's location on Skiatook Lake. Each site is represented by a yellow pin is tagged with a site number. Samples were collected, put on ice, and then sent to an analytical laboratory.

Sampling Methods

All the samples collected by the U.S. Army Corps of Engineers were analyzed using the U.S. Environmental Protection Agency's (EPA) methodology by the Tulsa City-County Health Department. The water quality parameters used in this analysis include total phosphorus, total Kjeldahl nitrogen, Secchi disk readings, turbidity, and Chlorophyll a. Method code 365.4 was used for analysis of total phosphorous and code 351.1 was used to analyze total Kjeldahl nitrogen. Total Kjeldahl nitrogen is the ammonia value plus the organic nitrogen value (Esralew et. al. 2011). Total phosphorus and total Kjeldahl nitrogen are both measured in milligrams per liter (mg/l). Turbidity is recorded in Nephelometric Turbidity Units (NTU) and Secchi disk depths are measured in meters (m). Chlorophyll a was measured by micrograms per liter (ug/l).

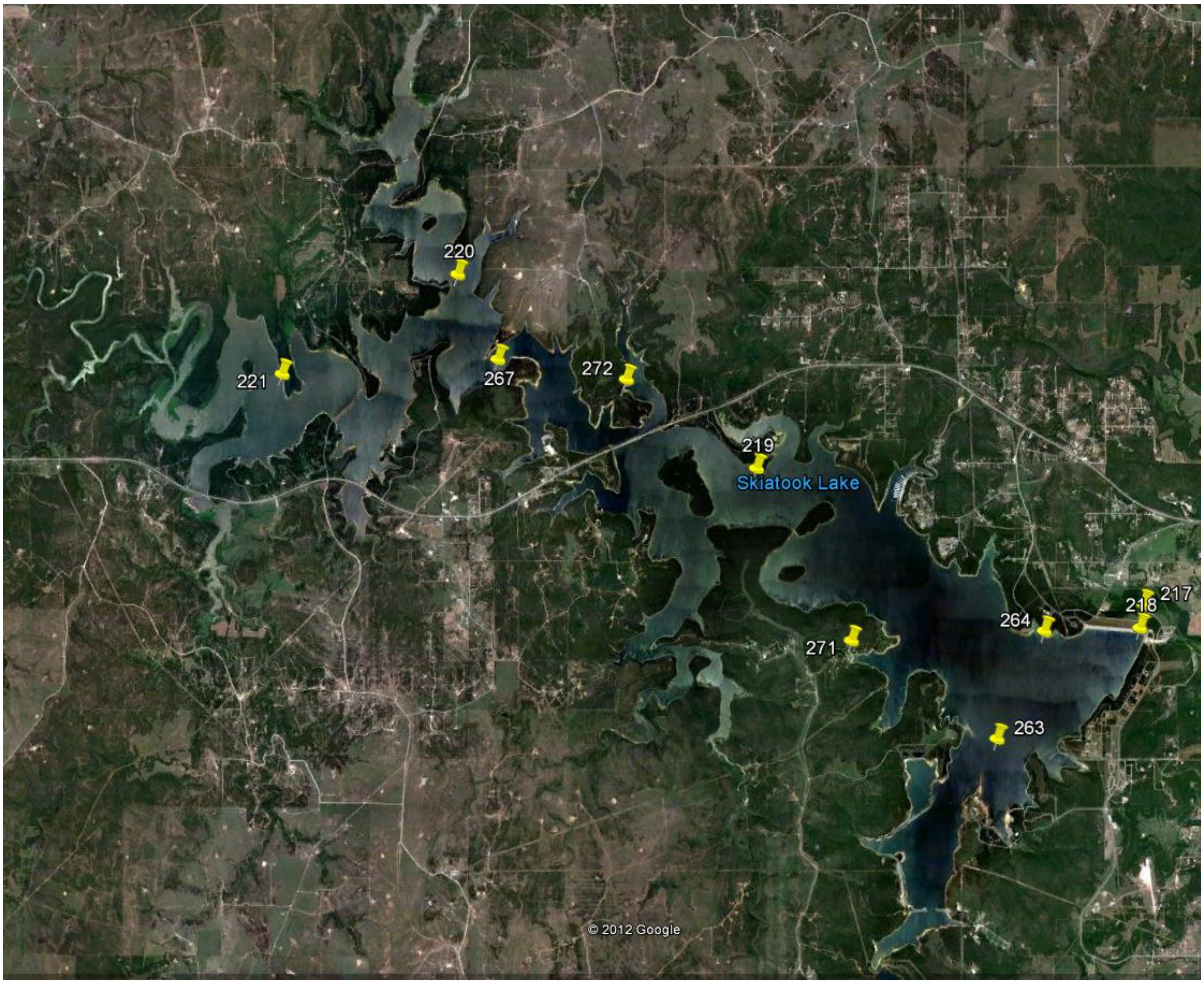

Figure 4. Sampling sites on Skiatook Lake. Source: Google Earth.

Statistical Analysis

Surface water nutrient concentrations were analyzed in this paper for 1994, 2003, and 2004 in Skiatook Lake. Separate analysis for each year was performed. Hypothesis testing of all water characteristics, TP, TKN, turbidity, and Secchi disk depths, was used to determine if there was a significant change from 1994 to 2004. All the sites were combined for each year and analyzed by year. This was done to account for any sparsity in data, and to create a larger sample size. A parametric analysis was then used; analysis of variance (ANOVA), one-way. ANCOVA was calculated with a statistical significance at p=0.05. The null hypothesis was accepted if there was no significant change in data (p was less than or equal to 0.05) and the data showed a decline rather than increase.

Tables were created in Microsoft Excel 2010 depicting descriptive statistics for each parameter. The tables include minimum and maximum value, mean, median, standard deviation, number of samples collected, and the number of values that fell below the detection limit. Scatterplots for all three years combined were created in Microsoft Excel. Scatterplots were created to show if there is a trend with water quality characteristics v. time. Individual water quality characteristics for each year are represented on scatterplots with a regression line. Other scatterplots and the box plots were made using Minitab Version 16 (2010). Boxplots are used to summarize distribution, range, skewness, and median of the data sets. A line graph was used to show any relationship/correlation between turbidity and total phosphorus. The line graph was also created in Microsoft Excel 2010.

CHAPTER IV

FINDINGS

Raw data (Appendix 1) was collected by the U.S. Army Corps of Engineers. This paper analyzed the concentrations of TP and TKN, along with turbidity levels and Secchi disk readings, lake wide. ANOVA statistical analysis was used to assess the relationship between all 3 years, for all 10 sites combined, on each characteristic. This one-way analysis of variance is used to compare independent samples. Statistical significance was determined at $p=0.05$. Boxplots were compiled to show the results from ANOVA.

To gain an insight on Skiatook Lake's water quality from 1994 to 2004, 4 parameters were analyzed: total phosphorus, total Kjeldahl nitrogen, Secchi disk readings and turbidity. Samples were taken from 10 different sites. Site numbers 218, 219, 220, and 221 were the only sites where samples were collected for all 3 years. Site number 218 is located on the east side of the dam. Site number 219 is located near the center of the lake, on the north side. Site 220 is near Bull Creek, a major tributary, on the northwest side of Skiatook and site 221 is located near

Hominy Creek, at the farthest western point. Each site evenly represents different point within the lake from east to west. Due to the fact that all sites weren't sampled, all sites were combined for each year and analyzed separately. Scatterplots allowed for month to month comparisons where as some graphs combined all the samples taken together per year.

Total Phosphorus

The majority of the samples of TP were taken from the 4 main sites; 91 of 117. During 1994, 60 samples were taken; in 2003 and 2004, a combined 62 samples were taken. For all 10 sites the TP ranges from 0.003 mg/l to 0.4 mg/l in 1994. In 2003, TP ranges from 0.021 to 0.148 mg/l. Total phosphorus ranged from 0.21 to 0.38 mg/l in 2004. The number of samples that fell below detection limits was 24 which all occurred in 1994. In 2003 and 2004 there has been an apparent rise in TP because there are no samples that were taken that fell below the detection limits. Table 1 depicts descriptive statistics and graphical summaries of lake wide results are in Figures 5, 6, 7, 8, 9, and 10.

Table 1. Descriptive statistics for total phosphorus (mg/l) on Skiatook Lake for the 1994, 2003, and 2004 sampling period.

Year	Min.	Max.	Mean	Median	St. Dev.	# Samples	# of Obs. BDL[l]
1994	0.003	0.400	0.0473	0.020	0.0711	60	24
2003	0.021	0.148	0.0546	0.037	0.0354	15	0
2004	0.021	0.101	0.0422	0.035	0.0225	42	0

[l]BDL= Below Detection Limit

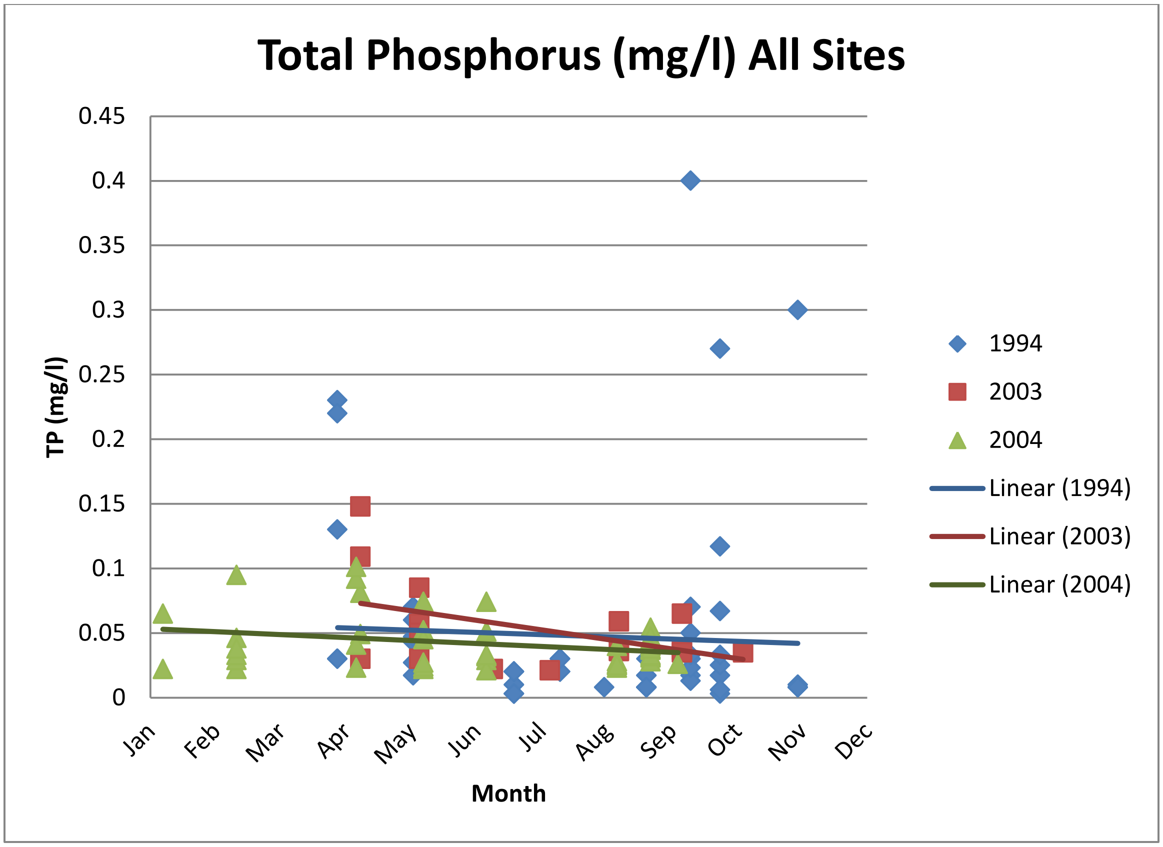

Figure 5. Scatterplot of total phosphorus (mg/l) for all sampling sites on Skiatook Lake for 1994, 2003, and 2004 study period.

Figure 5 compares all sited combined together. This graph shows month to month comparisons and accounts for any seasonal variations. The year 1994 appears to contain the most outliers (5) from the rest of the data, but has the largest sample size. The highest reading was taken in October of 1994; it is 0.4mg/l. Regression lines were inserted to show if the data was decreasing or increasing throughout the year. All three show a slight drop from when the samples were first taken until the end. The year 2003 appears to have the largest drop. Trend lines also depicted a decrease from one year to the next; 2003 and 2004 had the largest separation.

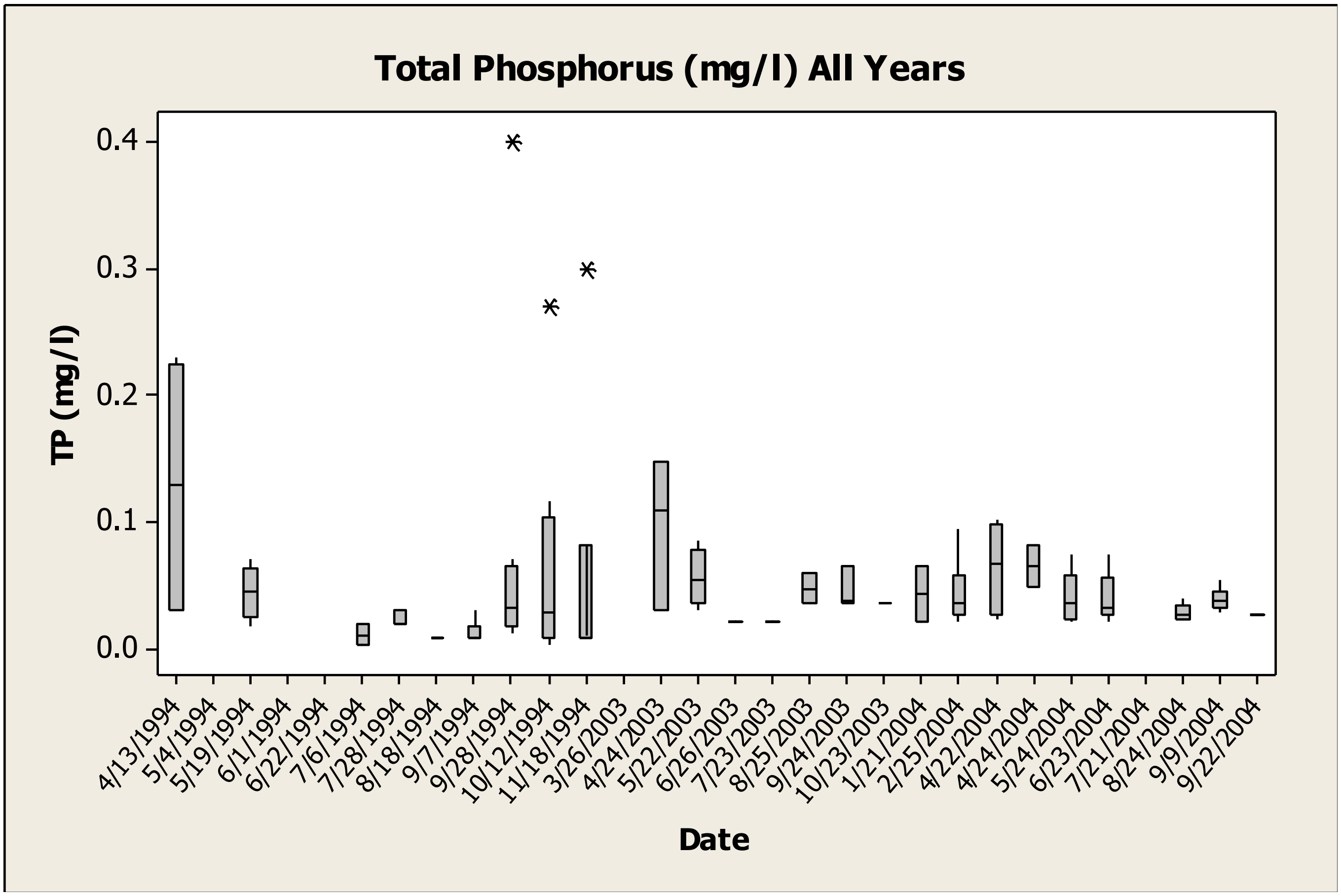

Figure 6. Boxplot of total phosphorus (mg/l) for all sampling sites and each day on Skiatook Lake for 1994, 2003, 2004 sampling period.

Figure 6 takes all the dates that were sampled for 1994, 2003, and 2004 and provides a boxplot with phosphorus levels. April of 1994 had the highest mean for TP. This boxplot shows 3 extreme outliers that occurred during 1994. In general, the mean for all three years fell below 0.1 mg/l. April of 1994 and April of 2003 both have a mean above 0.1mg/l. The widest distribution of data was in April of 1994.

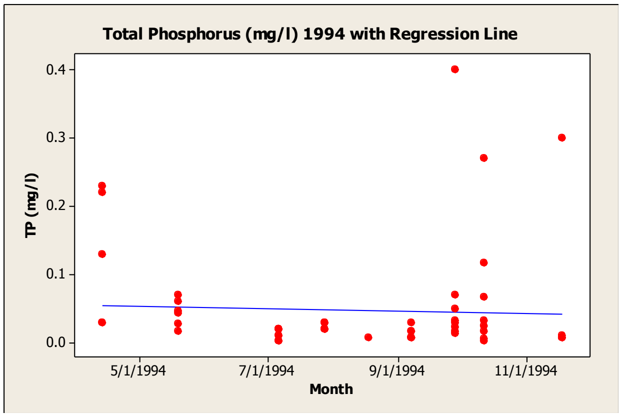

Figure 7. Scatterplot of total phosphorus (mg/l) for all sites on Skiatook Lake in 1994.

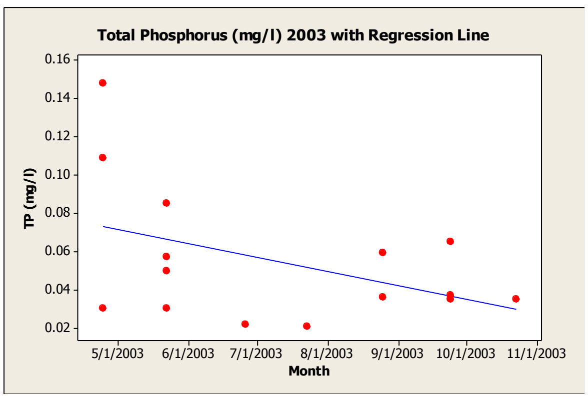

Figure 8. Scatterplot of total phosphorus (mg/l) for all sites on Skiatook Lake in 2003.

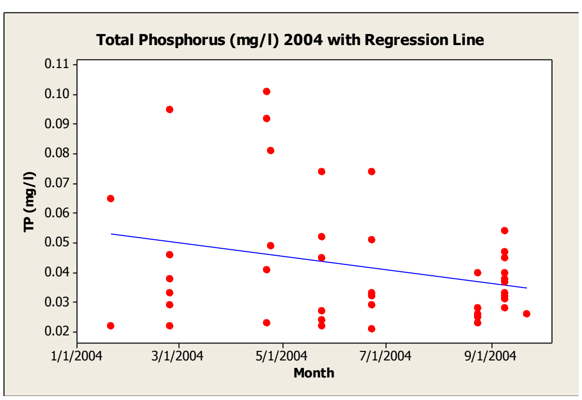

Figure 9. Scatterplot of total phosphorus (mg/l) for all sites on Skiatook Lake in 2004.

Figures 7, 8, and 9 shows TP for 1994, 2003, and 2004 separated from one another. The regression line shows a decreasing trend in the levels of TP each year. The regression line holds steady in 1994 between 0 and 0.1 at approximately 0.06 mg/l. In 2003, the regression line drops from approximately 0.075 to 0.035 mg/l. The year 2004, the regression line falls from 0.054 to 0.035 mg/l. A simple boxplot below, figure 9, show all three years means fall below 0.05 mg/l.

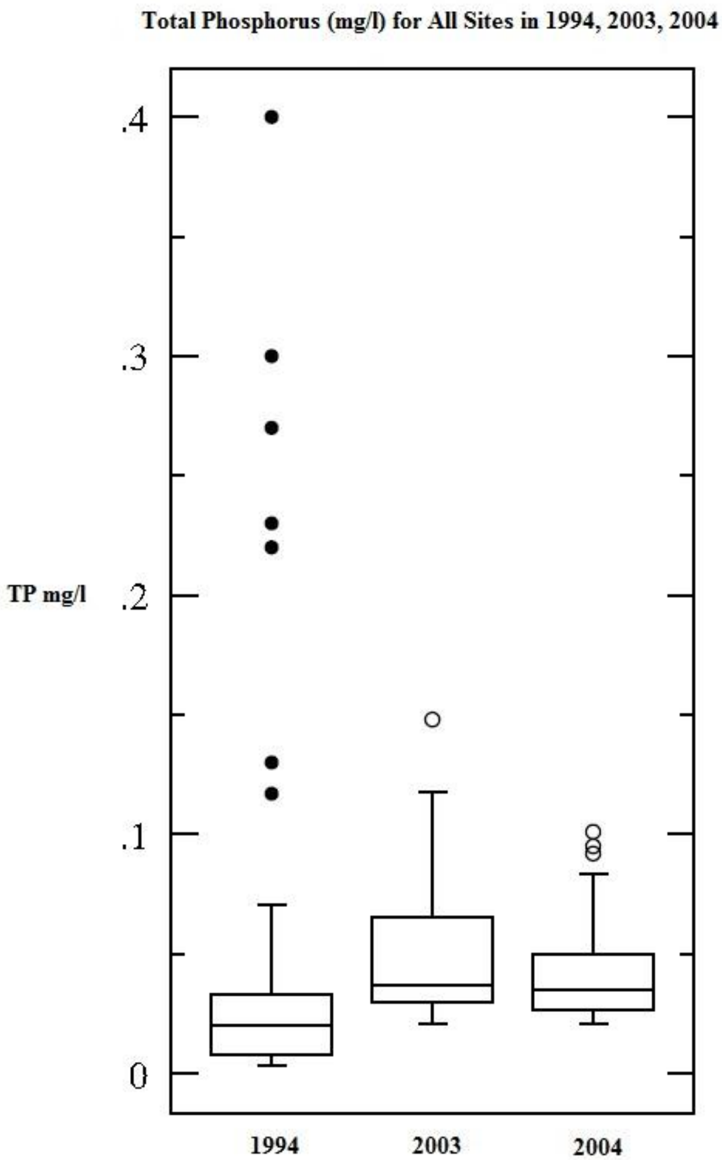

Figure 10. Boxplot of the total phosphorus data for all sites in 1994, 2003, 2004 study period.

When comparing the mean from all 3 years, Figure 10 shows a significant increase in TP from 1994 to 2003 from 0.02 mg/l to 0.035 mg/l. There was a slight decrease from 2003 to 2004. Suspected outliers are represented as circles and outliers are represented by solid black circles. ANOVA was used to calculate the independent samples; means, standard deviation, and probability for TP. In 1994, the mean for all the values was 0.0473 mg/l for a total of 60 samples. In 95% of all samples for 1994, the true value of TP will be captured by the interval (0.0322, 0.0624).The data was normally distributed. A total of 15 samples were taken in 2003 with a mean of 0.0546 mg/l. In 95% of all samples for 2003, the true value of TP will be captured by the interval (0.0244, 0.0424). In 2004, 42 samples were taken, with a mean of 0.0422 mg/l. In 95% of all samples in 2004, the true value of TP will be captured by the interval (0.0242, 0.0603). ANOVA results showed $F(2,114) = 0.26$. The probability of the result is $P=0.776$; showing a significant change in the amount of TP present in lake Skiatook from 1994 to 2004.

Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen was sampled at 10 different sites. All of the data was combined for each site and was analyzed together. The majority of the samples were taken from these 4 sites; 154 of 221. For all 10 sites the total Kjeldahl nitrogen ranges from .07 mg/l to 1.08 mg/l in 1994. It ranges from 0.19 to 1.27 mg/l in 2003 and from 0.07 to 0.74 mg/l in 2004. Zero samples fell below detection limits. Table 2 discusses the descriptive statistics and graphical summaries of lake wide results are in Figures 11, 12, 13, 14, 15, and 16.

Table 2. . Descriptive statistics for toatl Kjeldahl nitrogen (mg/l) on Skiatook Lake for the 1994, 2003, and 2004 sampling period.

Year	Min.	Max.	Mean	Median	St. Dev.	# Samples	# of Obs. BDL[l]
1994	0.15	1.08	0.5692	0.5550	0.3411	50	0
2003	0.19	1.27	0.4251	0.4000	0.1887	67	0
2004	0.07	0.74	0.4160	0.4000	0.1380	96	0

[l]BDL= Below Detection Limit

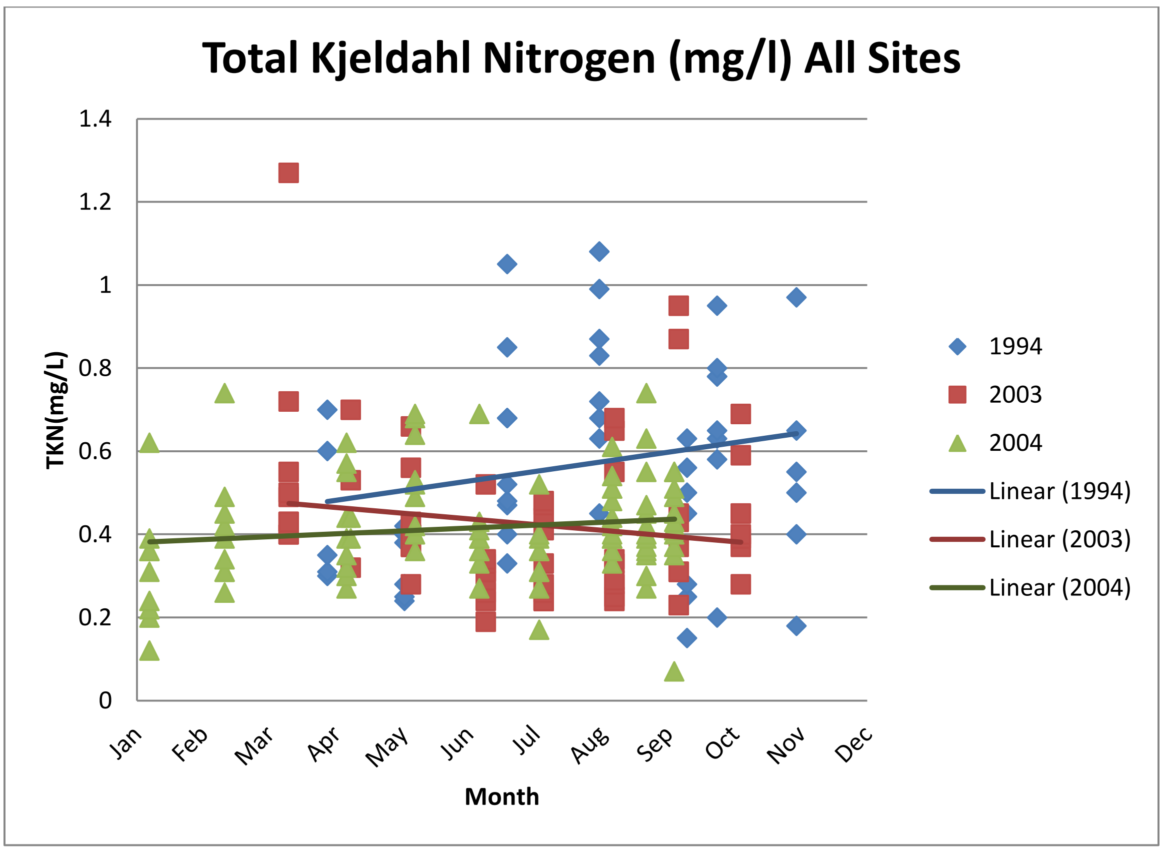

Figure 11. Scatterplot of total Kjeldahl nitrogen (mg/l) for all sampling sites on Skiatook Lake for 1994, 2003, and 2004 study period.

Figure 11 shows all samples taken in the sampling years. This graph shows month to month comparisons and accounts for any seasonal variations. In 2003, there is one outlier at

1.27mg/l and in 2004 there is one in September. Trend lines were used to demonstrate the changes that occurred within each individual year. They also show that there is a larger difference in TKN between the years 1994 and 2004.

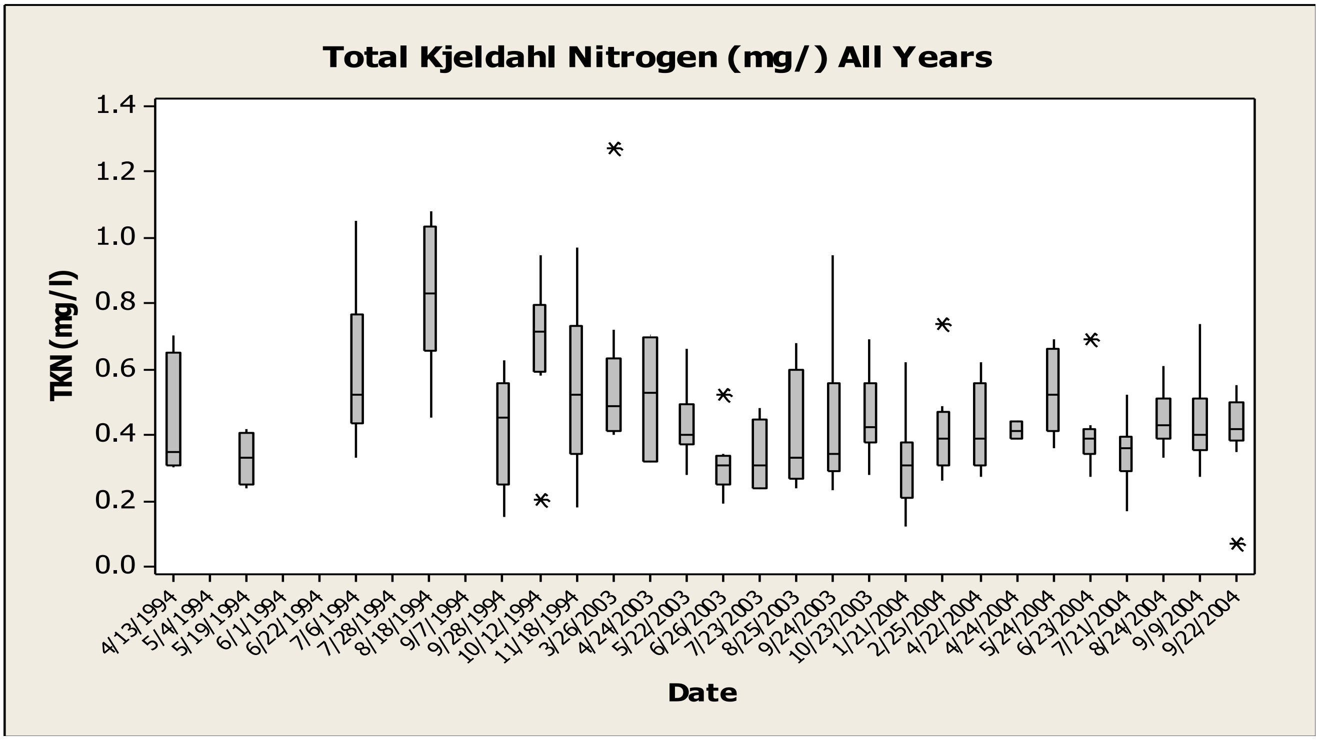

Figure 12. Figure 5. Boxplot of total Kjeldahl nitrogen (mg/l) for all sampling sites and each day on Skiatook Lake for 1994, 2003, 2004 sampling period.

Figure 12 is a boxplot containing all the dates when samples were taken. This graph shows 6 outliers; 4 above and 2 below. There is a slight decreasing trend in TKN from 1994 to 2004. November of 1994 has the widest spread of data. July of 1994 has the highest values. When referring back to the precipitation graphs (Figures 1 & 2), July and August received the highest amount of rainfall for the year. In 2003, the highest values are in April and in 2004 they are in May.

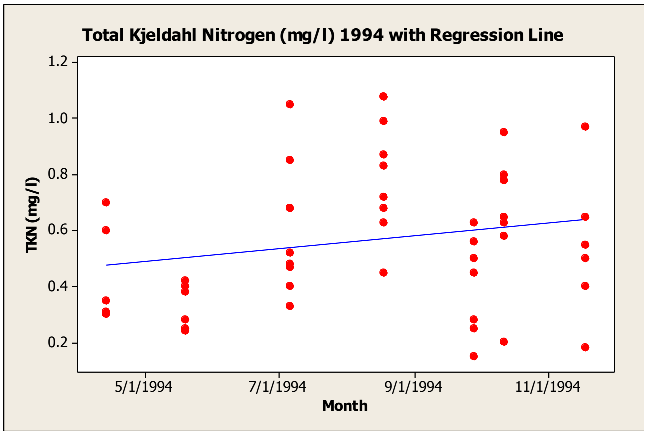

Figure 13. Scatterplot of total Kjeldahl nitrogen (mg/l) for all sites on Skiatook Lake in 1994.

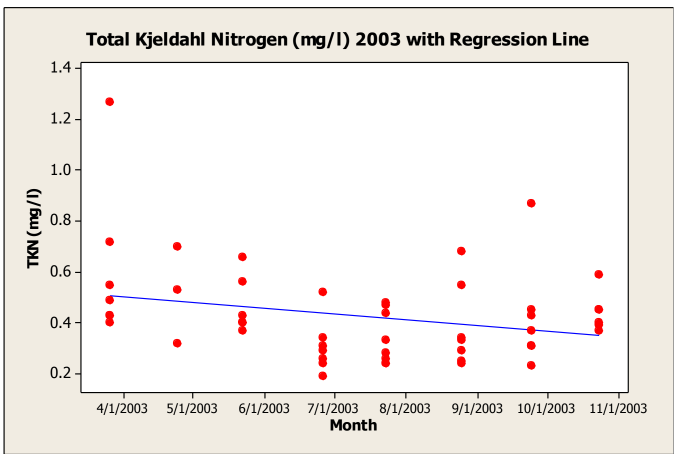

Figure 14. Scatterplot of total Kjeldahl nitrogen (mg/l) for all sites on Skiatook Lake in 2003.

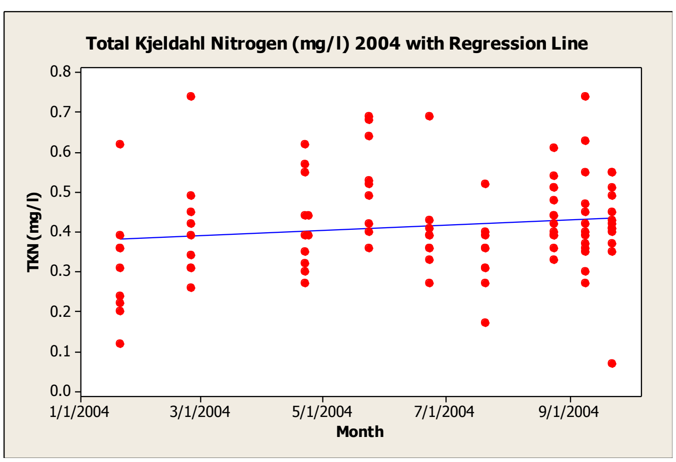

Figure 15. Scatterplot of total Kjeldahl nitrogen (mg/l) for all sites on Skiatook Lake in 2004.

Figures 13, 14, and 15 are scatterplot for TKN, separated into each individual year with a regression line. The first graph, 1994, shows a slight increase trend in TKN from 0.5 to 0.65 mg/l. In 2003, the line falls from 0.5 to 0.4 mg/l and in 2004 it begins at 0.37 and rises to 0.42. Figure 18 shows the means of each year is between 0.4 to 0.57 mg/l.

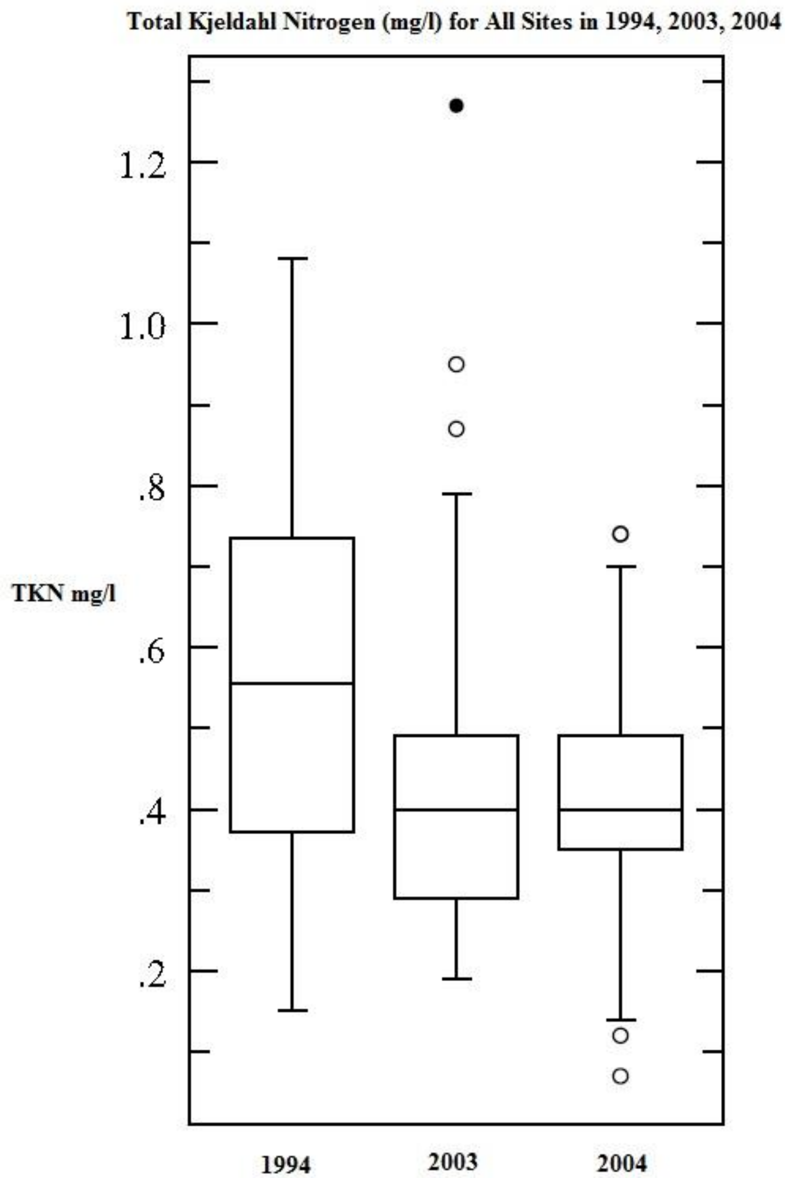

Figure 16. Boxplot of the total Kjeldahl nitrogen data for all sites in 1994, 2003, 2004.

Figure 16 is a boxplot representing TKN v. 1994, 2003, and 2004. Suspected outliers are represented as circles and outliers are represented by solid black circles. Just by assessing the graph, it's apparent there is no significant change from one year to the next. Using ANOVA, means, standard deviation, and probability were all calculated for each independent year. In 1994, the mean for all the values of TKN was 0.5692 mg/l for a total of 50 samples. In 95% of all samples for 1994, the true value of TKN will be captured by the interval (0.5184, 0.6200). This data is normally distributed. A total of 67 samples were taken in 2003 with a mean of 0.4251 mg/l. In 95% of all samples for 2003, the true value of TKN will be captured by the interval (0.3812, 0.4689). In 2004, 96 samples were taken, with a mean of 0.4160 mg/l. The data is skewed to the right. In 95% of all samples, the true value of TKN will be captured by the interval (0.3794, 0.4527). Probability was calculated to find if there was a significant change in TKN over the 10 year period. ANOVA results showed $F(2,210) = 12.93$. The probability value for TKN was $P=0.0001$. There wasn't a significant change in TKN over the 10 years that the samples were collected.

Turbidity

Turbidity was sampled at 10 different sites. The majority of the samples were taken from 4 sites; 148 of 201. Turbidity readings were heavily collected for the year 1994. For all 10 sites the turbidity ranges from 0.3 NTU to 645 NTU in 1994. In 2003, turbidity ranges from 0.2 to 373 NTU. Turbidity ranged from 0.6 to 219 NTU in 2004. The number of samples that fell below detection limits was 24. Table 3 discusses the descriptive statistics for each year and graphical summaries of lake wide results are in Figures 17, 18, 19, 20, 21, and 22. Log scale was utilized in figure 17 so that the smaller turbidity values (NTU) can well visualized along with the outliers.

Table 3. Descriptive statistics turbidity (NTU) on Skiatook Lake for the 1994, 2003, and 2004 sampling period.

Year	Min.	Max.	Mean	Median	St. Dev.	# Samples
1994	0.3	645	27.9319	5.9	86.5041	85
2003	0.2	373	25.3689	8.1	48.5757	45
2004	0.6	219	20.2746	9.1	29.6160	71

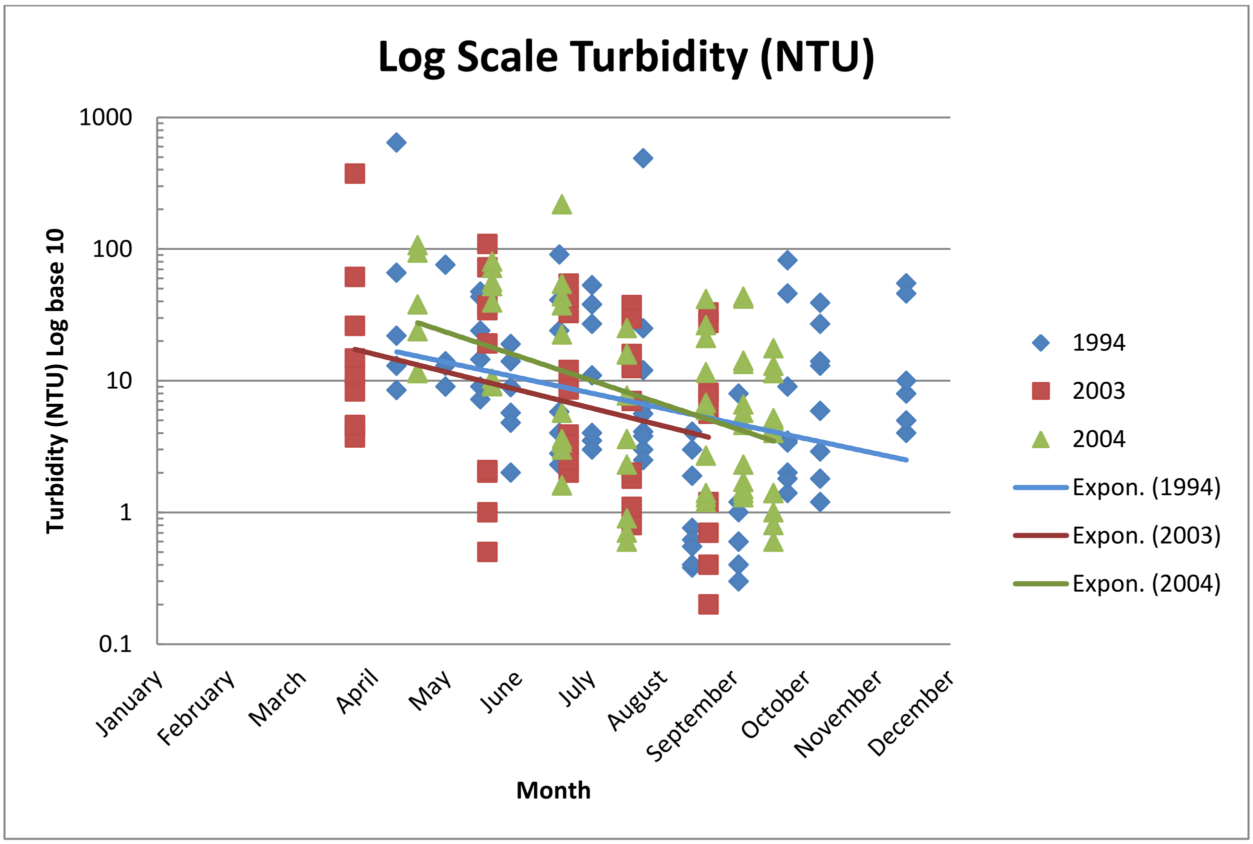

Figure 17. Scatterplot of turbidity (NTU) for all sampling sites on Skiatook Lake for 1994, 2003, and 2004 study period.

Figure 17 is a scatterplot depicting turbidity values for all three years in a logarithmic scale with a base of 10. An exponential trend line was used for all three years. In 1994, there was a decrease from April until November. The year 2003 showed a decrease from March until October and 2004 had decreased from January until September. Data for this parameter was heavily collected in 1994, 85 samples. The maximum measurement was recorded in this year (645 NTU).

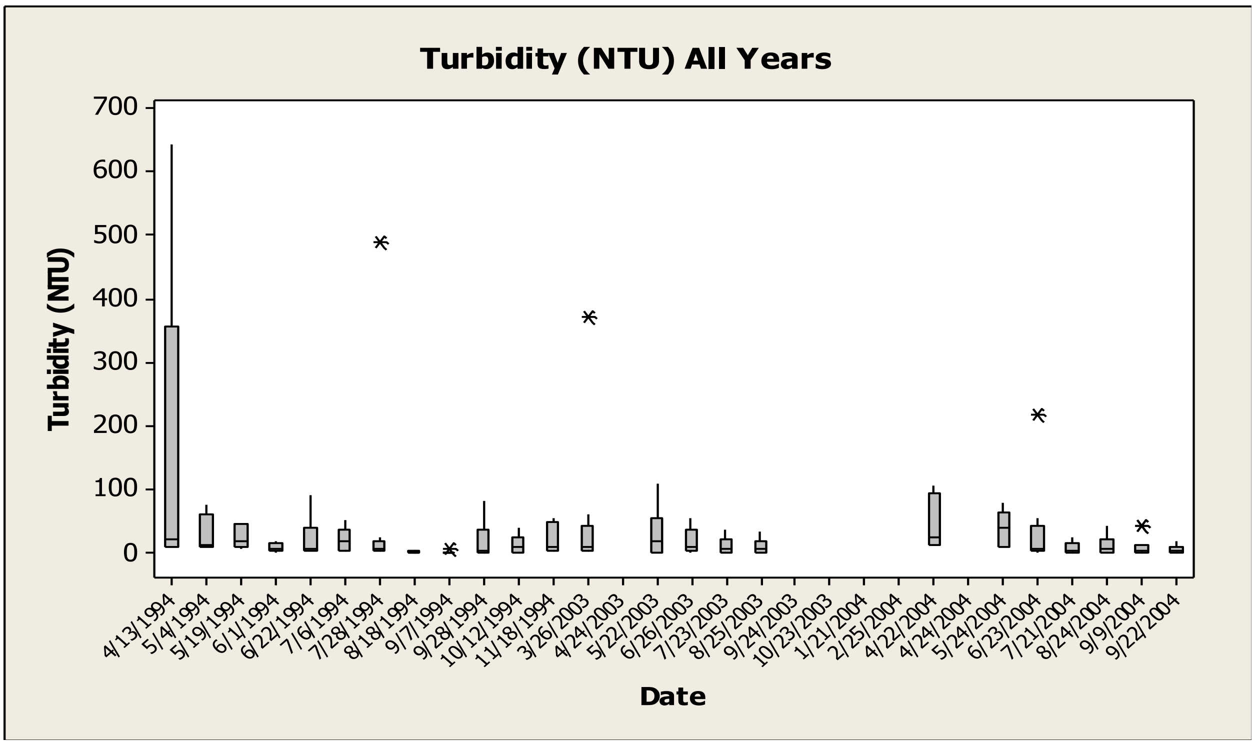

Figure 18. Boxplot of turbidity (NTU) for all sampling sites and each day on Skiatook Lake for 1994, 2003, 2004 sampling period.

This boxplot represent all the sites and each date that a sample was collected. Turbidity appears to have the largest distribution of values in April of 1994 and is skewed heavily to the right. Three extreme outliers lie in July of 1994, March of 2003, and June of 2004. Means of all sites fall below 58 NTU.

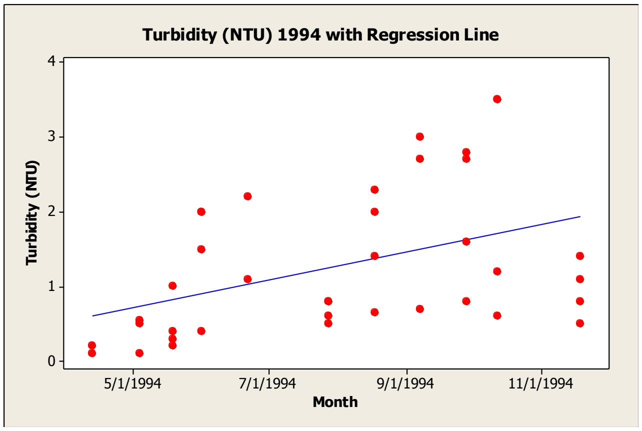

Figure 19. Scatterplot of turbidity (NTU) for all sites on Skiatook Lake in 1994.

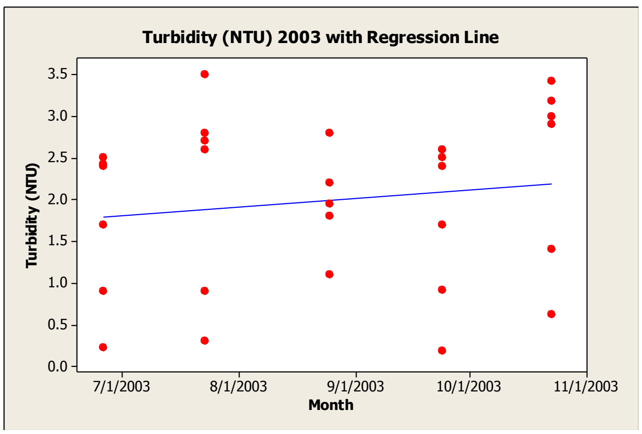

Figure 20. Scatterplot of turbidity (NTU) for all sites on Skiatook Lake in 2003.

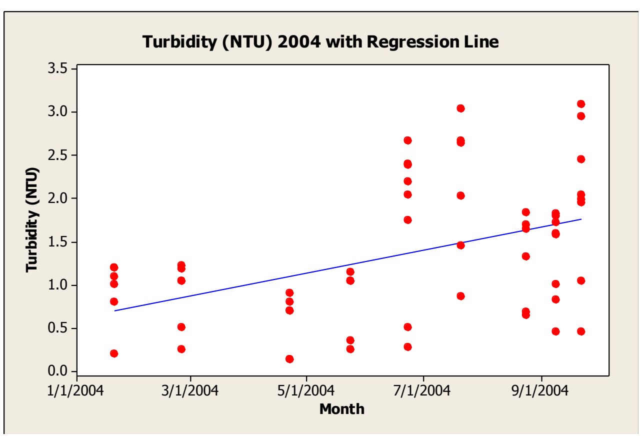

Figure 21. Scatterplot of turbidity (NTU) for all sites on Skiatook Lake in 2004.

The scatterplots, with regression lines, all show a slight decrease of turbidity throughout each year. 1994 had the highest reading of NTU, 645. Turbidity remained higher for 1994 and 2003. It then drops to approximately half of that value in 2004 and continues to decrease as the year progresses.

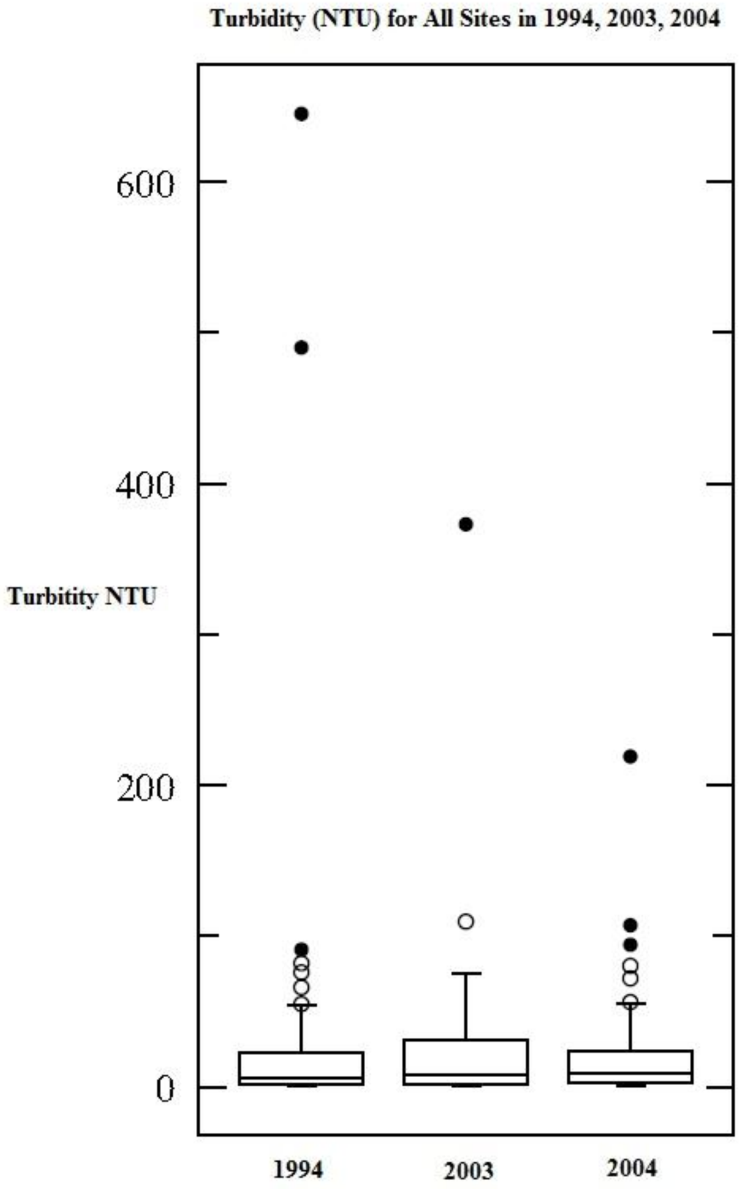

Figure 22. Boxplot of the turbidity data for all sites in 1994, 2003, 2004.

Figure 23 is a boxplot for all 3 years sampled and provides a visual of the distribution of data. Suspected outliers are represented as circles and outliers are represented by solid black circles. Using ANOVA to compare the independent samples; means, standard deviation, and probability were also calculated for turbidity. Each year had a right skew in data. In 1994, the mean for all the values was 27.932 NTU for a total of 85 samples. In 95% of all samples, the true value of turbidity will be captured by the interval (13.79, 42.07). A total of 45 samples were taken in 2003 with a mean of 25.369 NTU. In 95% of all samples, the true value of turbidity will be captured by the interval (5.936, 44.80). In 2004, 71 samples were taken, with a mean of 20.275 NTU. In 95% of all samples, the true value of turbidity will be captured by the interval (4.804, 35.75). ANOVA results showed $F(2, 198) = 0.26$. The probability calculated for turbidity was $P=0.77$; showing a significant change in turbidity from 1994 to 2004.

Secchi Disk

Samples were taken from 8 sites around Skiatook Lake. Only 3 of the 8 sites were sampled for 1993, 2003, and 2004; 69 of 118 samples. In 1994, the minimum value was 0.1m, in 2003, the minimum value was 0.18m, and in 2004, 0.13m was the minimum. The maximum was 3.5m for 1994, 11m for 2003, and 1.793m for 2004. Table 4 discusses the descriptive statistics for all 3 years and graphical summaries are represented below in figures 23, 24, 25, 26, 27, and 28.

Table 4. Descriptive statistics for Secchi disk (m) on Skiatook Lake for the 1994, 2003, and 2004 sampling period.

Year	Min.	Max.	Mean	Median	St. Dev.	# Samples
1994	0.1	3.5	1.2763	0.9	0.9794	38
2003	0.18	3.5	1.9869	2.4	0.9866	29
2004	0.13	3.1	1.3442	1.165	0.7965	60

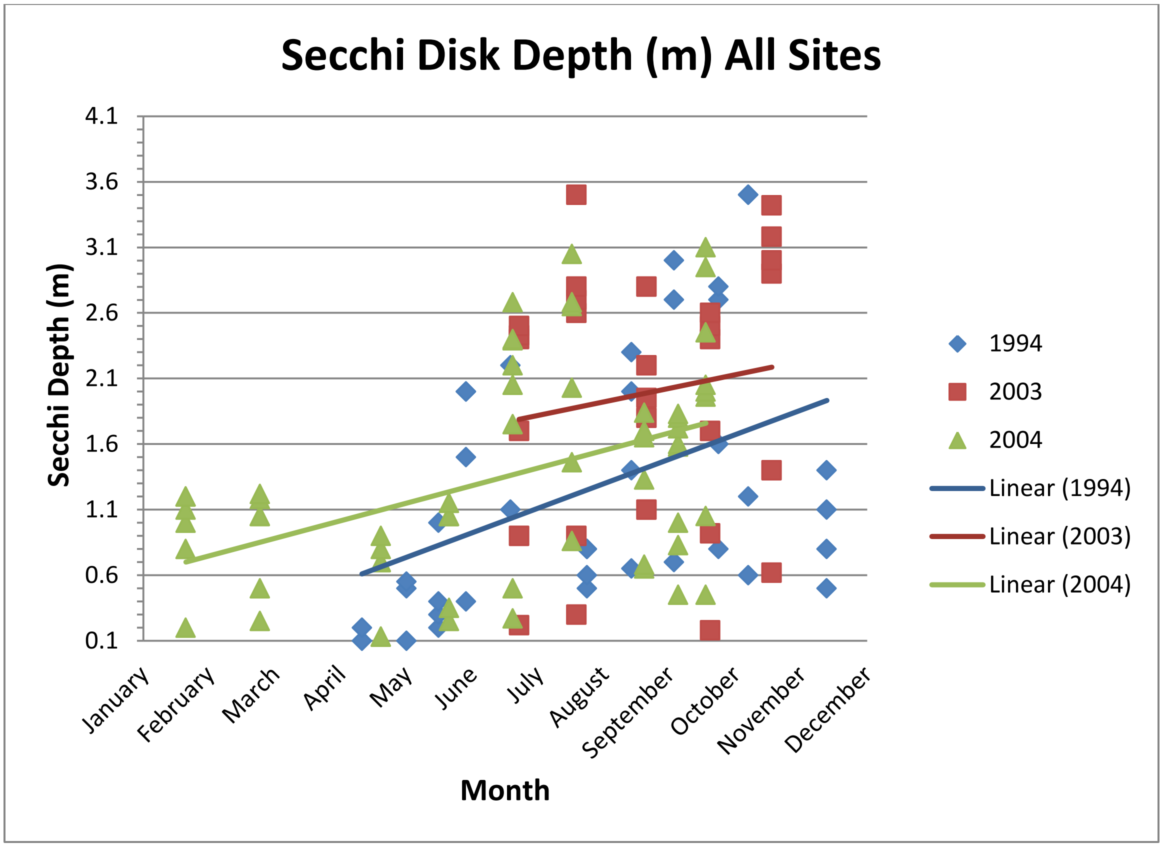

Figure 23. Scatterplot of Secchi disk (m) for all sampling sites on Skiatook Lake for 1994, 2003, and 2004 study period.

Figure 23 shows Secchi disk depths take from the 1994, 2003, and 2004 sampling times. Trends show that the Secchi disk reading increase towards the end of the year; meaning increased clarity. Samples were taken from April until November in 1994, from July until October in 2003, and January until September of 2004. During 2003 reading are higher than 1994 and 2004. There is an aparent increase in Secchidisk depth from 1994 to 2003.

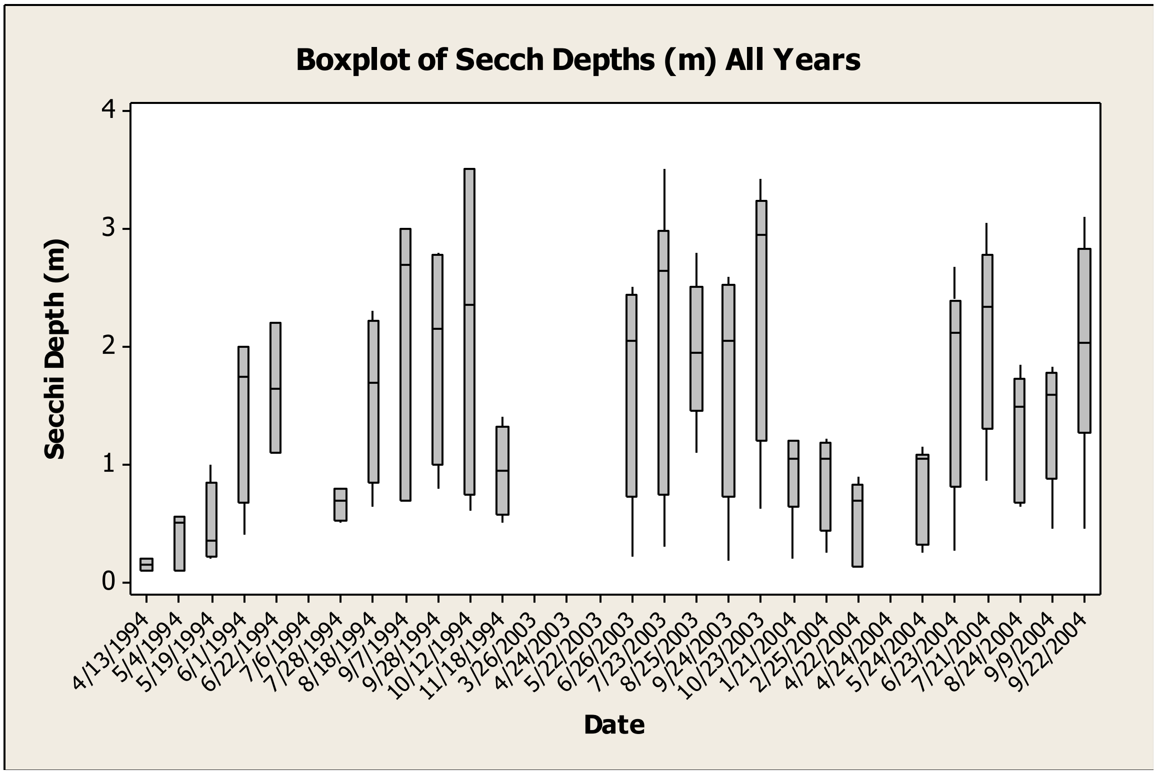

Figure 24. Boxplot of Secchi disk (m) for all sampling sites and each day on Skiatook Lake for 1994, 2003, 2004 sampling period.

This boxplot represent all the sites and each date that a sample was collected. Secchi depths appear to have the highest spread in values in July of 2003. Means of all sites fall below 2.8m. The majority of the boxplots are skewed to the left. The boxplots show heavy season trends; the clarity is much higher during the late summer and fall months.

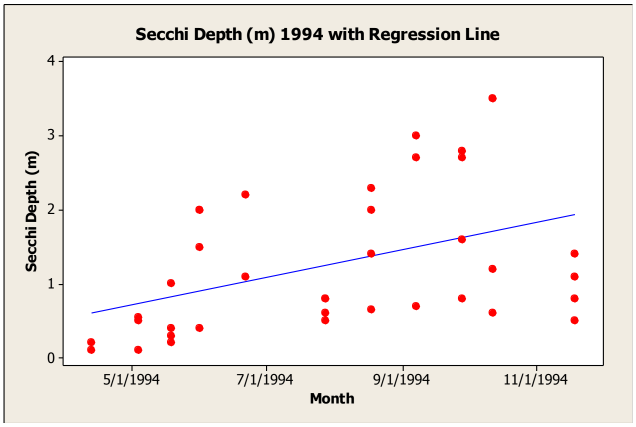

Figure 25. Scatterplot of Secchi disk (m) for all sites on Skiatook Lake in 1994.

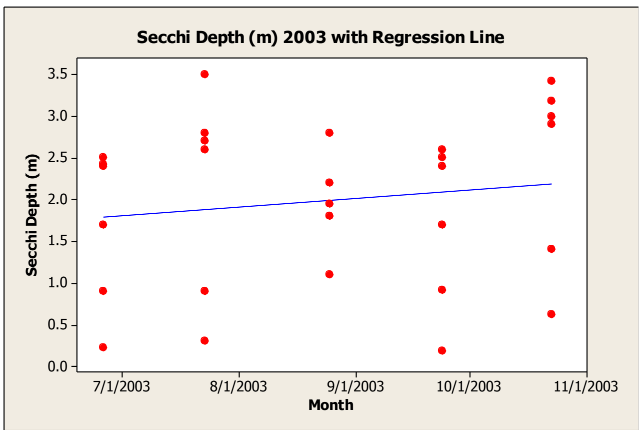

Figure 26. Scatterplot of Secchi disk (m) for all sites on Skiatook Lake in 1994.

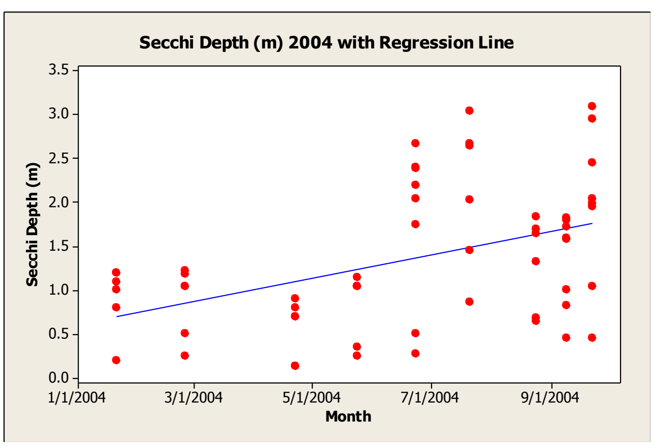

Figure 27. Scatterplot of Secchi disk (m) for all sites on Skiatook Lake in 1994.

The scatterplots, with regression lines, all show an increase of Secchi depths throughout each year. 2003 had the highest Secchi disk reading of 11m. Readings remained higher in 2003 than 1994 and 2004. Depending on the site, Secchi depths and turbidity drastically change from one end of the lake to the other.

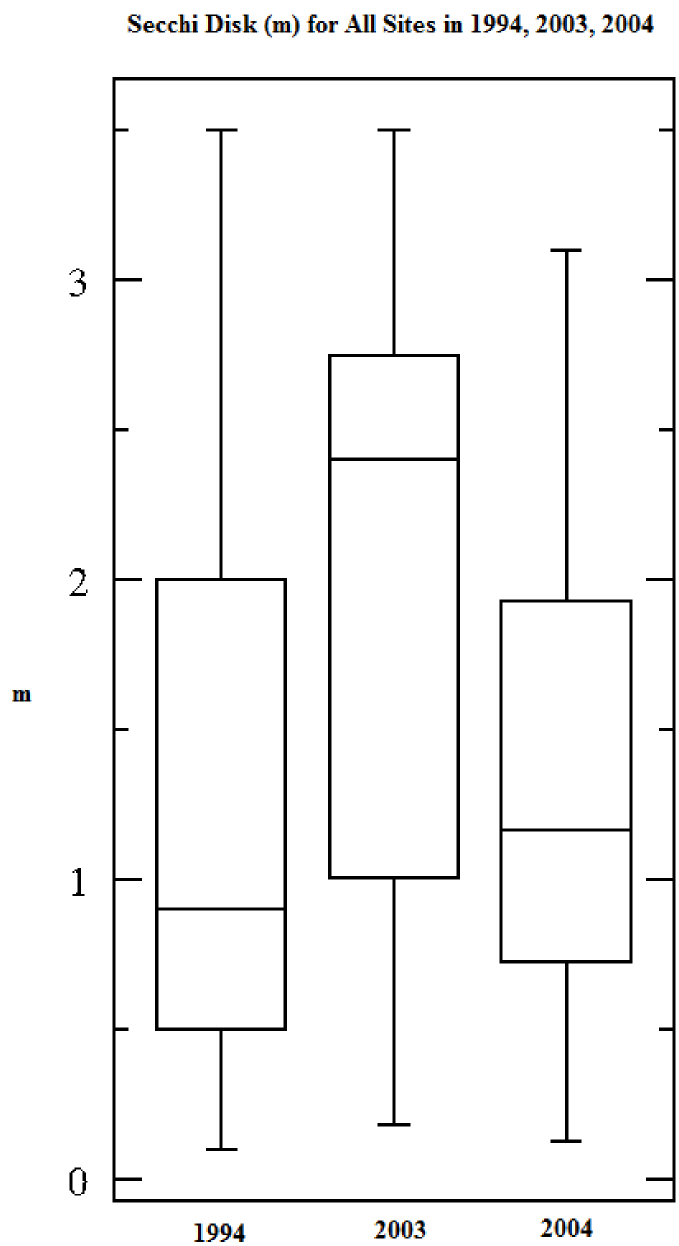

Figure 28. Boxplot of the Secchi data for all sites in 1994, 2003, 2004.

Figure 28 is a boxplot displaying the distribution of Secchi disk readings for 1994, 2003, and 2004. Suspected outliers are represented as circles and outliers are represented by solid black circles. Means for all years fall between 0.8m and 2.4m. Although the means vary significantly from each other, 95% of the data falls around the same values. ANOVA was utilized to calculate the independent samples; means, standard deviation, and probability for Secchi disk reading. In 1994, the mean for all the values was 1.28m for a total of 38 samples. In 95% of all samples, the true value of Secchi depths will be captured by the interval (0.9877, 1.565). A total of 29 samples were taken in 2003 with a mean of 1.987m. In 95% of all samples, the true value of Secchi depths will be captured by the interval (1.657, 2.317). In 2004, 60 samples were taken, with a mean of 1.344. In 95% of all samples, the true value of Secchi depths will be captured by the interval (1.114, 1.574). 1994 and 2004 was right skewed. 2003 was skewed to the left. ANOVA results showed $F\ (2,124) = 6.265$. Probability calculated for Secchi readings was $P=0.003$; clarity of the water in Skiatook Lake has remained constant from 1994 to 2004.

Chlorophyll a

Chlorophyll a should be positively correlated with total phosphorus; the higher the TP, the higher the chlorophyll values should be. As previously stated, TP levels showed a significant increase from 1994 to 2004. On the other hand, TP decreased from 2003 to 2004. Figure 29 is a boxplot of chlorophyll a from the years 2003 to 2004. Chlorophyll a data was not collected for 1994. This graph shows an increase in chlorophyll a means from 2003 to 2004. Figure 30 and 31 are scatterplots depicting the negative correlation that has occurred between chlorophyll a and total phosphorus for each separate year. The mean was used for each month and each year was examined separately.

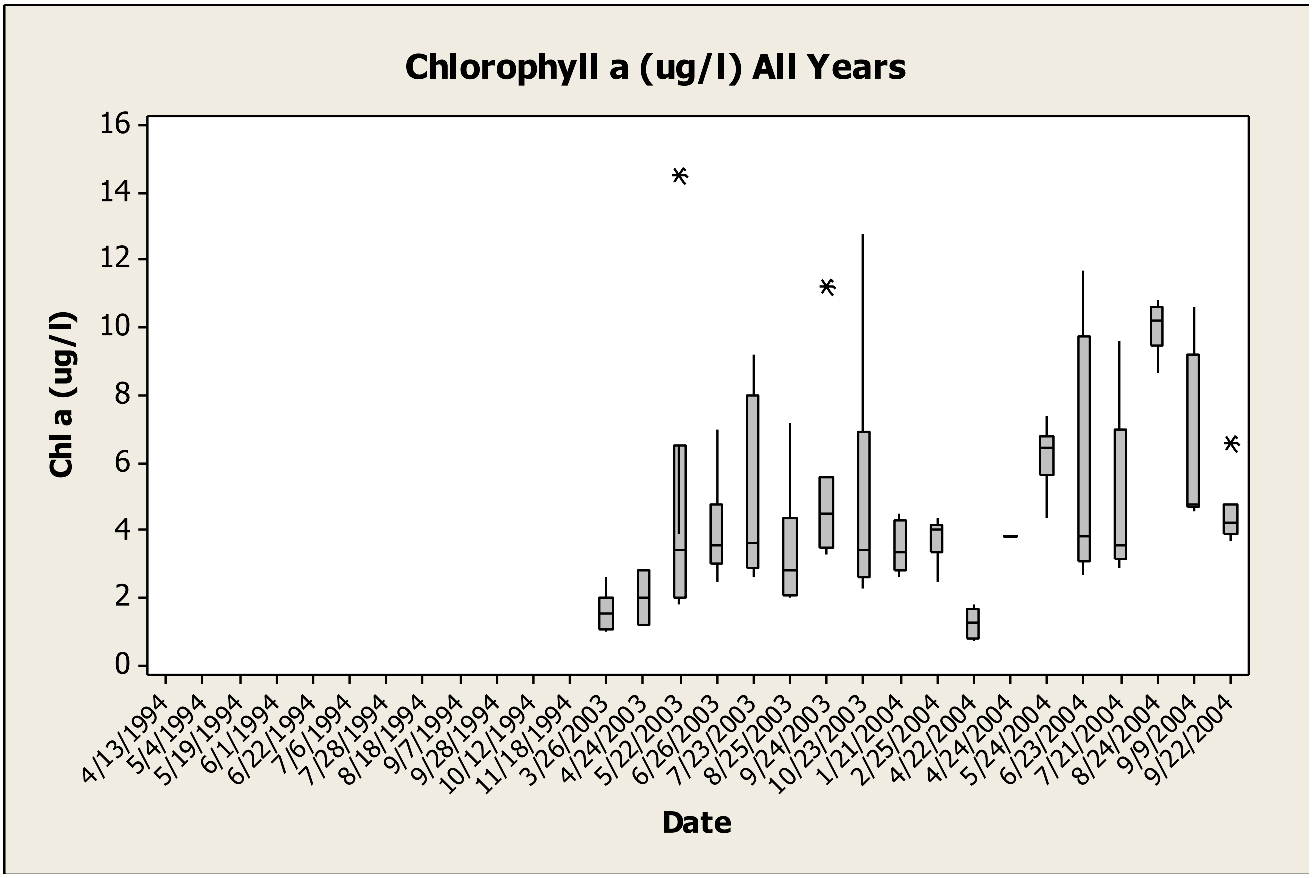

Figure 29. Boxplot of chlorophyll a (ug/l) for all sampling sites and each day on Skiatook Lake for 1994, 2003, 2004 sampling period.

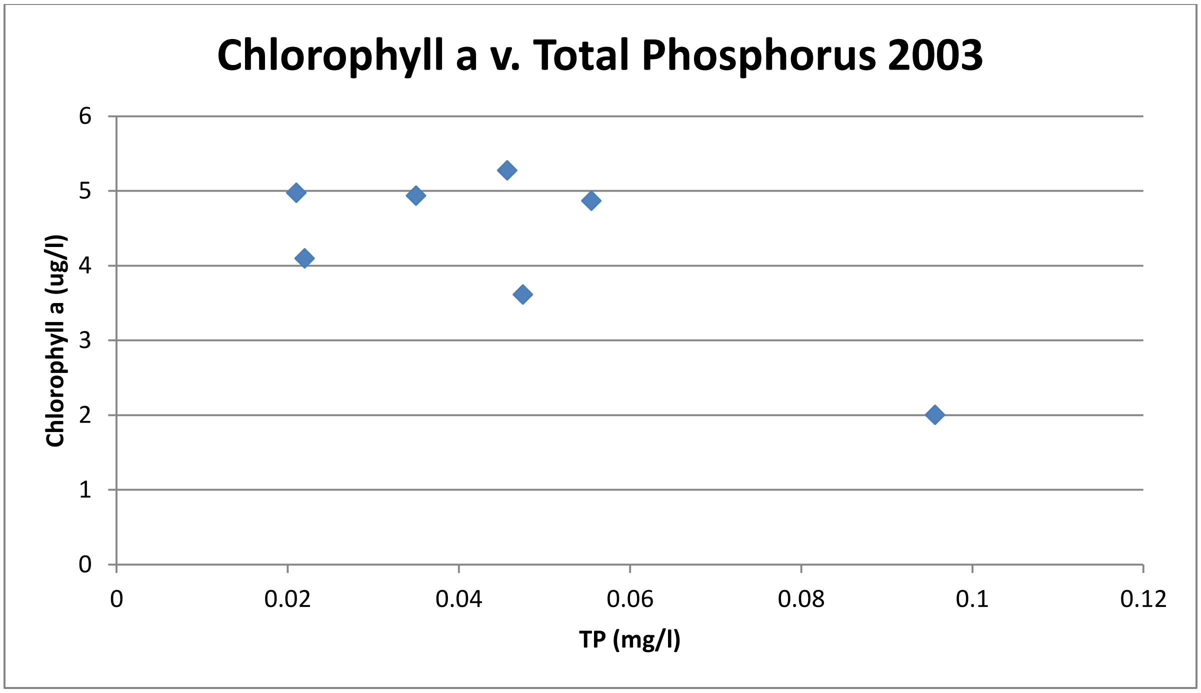

Figure 30. Scatterplot of chlorophyll a v. total phosphorus during the 2003 sampling period.

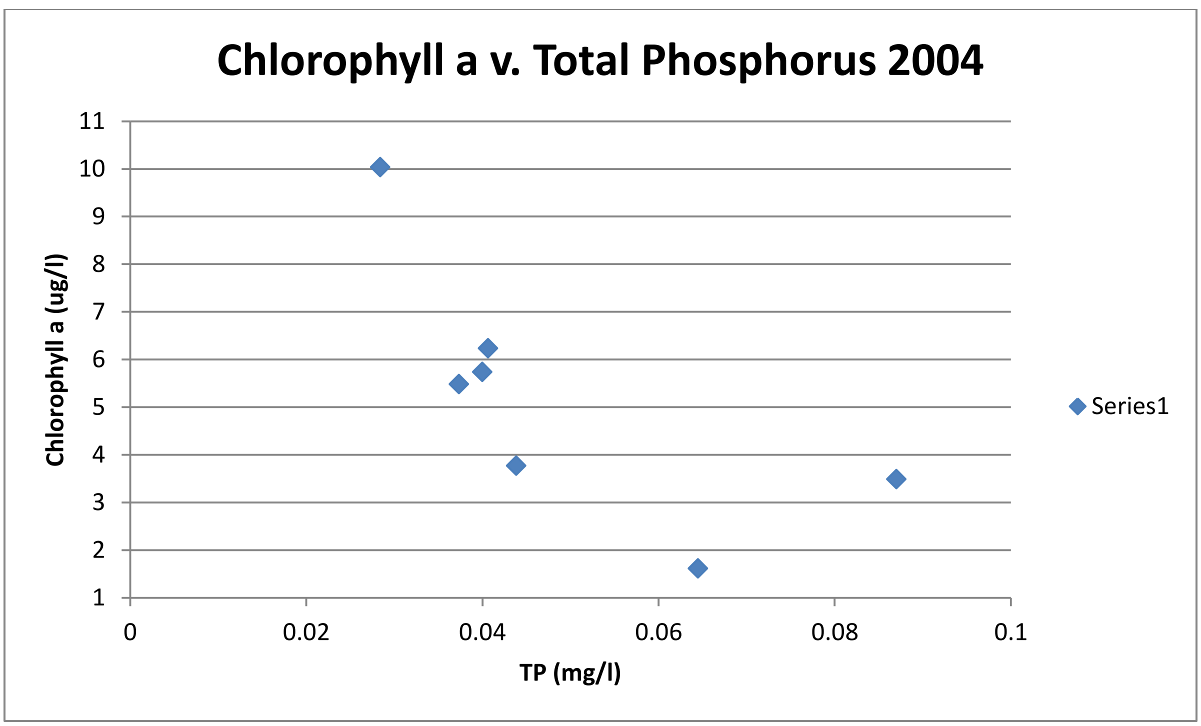

Figure 31. Scatterplot of chlorophyll a v. total phosphorus during the 2004 sampling period.

Correlations

Figure 32 depicts the relationship between total phosphorus and turbidity. A log base 10 was used so that the data points for both turbidity and TP can be well visualized on one graph. It clearly shows that during the years 1994, 2003, and 2004 there is a close relationship between the two variables. Due to this close correlation, recent studies have shown that turbidity may be used as a substitute measurement for TP (Kulasova et al. 2012 and Jones et. al 2011).

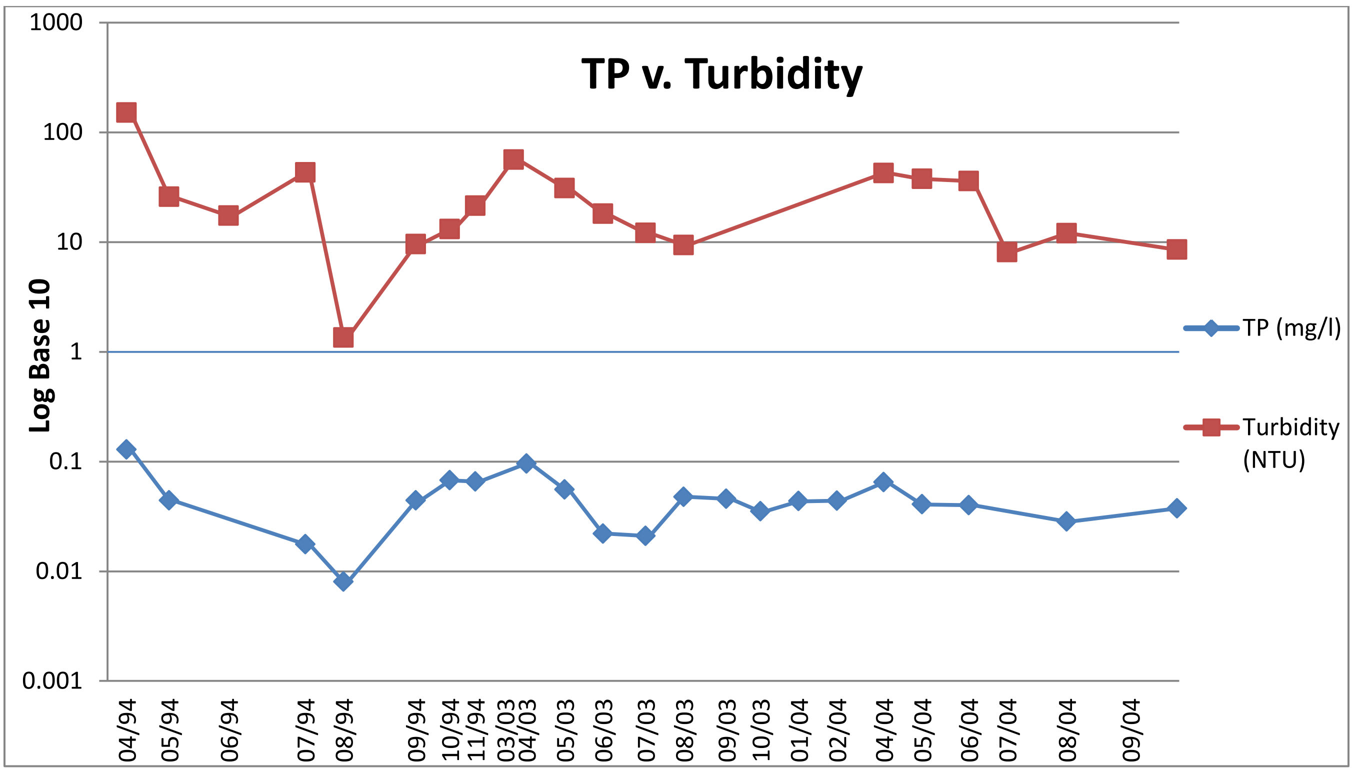

Figure 32. Line graph depicting TP (mg/l) and turbidity (NTU) for all 3 sampling periods.

CHAPTER V

DISCUSSION

Factors affecting ecosystem quality, anthropogenic and natural, vary spatially and temporally which makes analyzing water quality complex. Many techniques for sampling and analyzing the data are available. Assessing nutrient enrichment encompasses water quality, hydrodynamics, biological events, pollution sources, and even timing. Proper management depends on all of the aspects. The best way to approach such a widespread occurrence is to be proactive instead of reactive and to continue to closely monitor surface water.

Grab sampling occurs with in a small time period, for example, once a month. This represents a very small sample of the true population. Regardless, some seasonal effects can be observed during long sampling period. Biological uptake of TKN is higher in the spring; this can be seen in figure 11. Secchi depths also show seasonal trends. During the algal growing season (spring and summer) Secchi depths are low and then as the algae growth peaks, the readings begin to increase again. Concentration of these water quality parameters are also highly dependent on other timing; factors such as agricultural events. Agricultural events can include times when fertilization, herbicides, and pesticides are applied. Nutrients in runoff are also affected by whether fields have just been plowed or are fully grown.

Depending on the magnitude of a rainfall event, nutrient concentrations can be subject to flushing effects (Kulasova et al. 2012). When there are few but significant events, heavier runoff from nonpoint sources will occur. 1994 received the most rainfall, 48.1 inches and 2003 got the least, 36.6 inches. July of 1994 had an average of 11 inches, followed by 7 inches in April and November. Outliers for TP all occured within 1994. On September 28, a sample was taken with a

TP value of 0.4 mg/l. It had rained for 4 straight days. Another sample was taken on October 12, 1994 with a value of 0.27 mg/l. Within 5 days prior to the sample, it had rained 2.93 inches. In April and July of 1994, two high turbidity reading were taken. One was 645 NTU and the other 490 NTU; 3.62 inches and 2.88 inches had both fallen within 5 days prior to the sample collection. Secchi reading were also very low on the same day in April. In 2003, August got the most rain; a little more than 7 inches. During March, 3.4 inches fell within 7 days prior to the collection day, possibly increasing turbidity and TKN readings. December and January had the smallest volume of rain for all 3 years. Oklahoma experiences short durations of rain, but it comes with high intensities (Alexander Consulting Inc. 2003).

Samples taken during these peak runoff times may provide a better view of where the nutrients affecting the lake come from. Further analysis of daily rainfall would be beneficiary to discover its impact on water quality in Skiatook Lake. Outliers in the data may come from high intensity rainfalls or from specific sites that are notorious for poorer water quality. Further analysis of all parameters at each individual site (Appendixes 2-6) may be beneficial for implementing appropriate best management practices to reduce runoff from such nonpoint sources.

Data used for this study was randomly collected, not on specific dates or times, and in some cases could have introduced potential bias. Some sites weren't collected for all 3 years, while others were collected more often. For the purpose of overall lake management, it is sufficient to allow the data to be analyzed for significant change. Once a significant change has occurred and it is perceived as a problem, future use of continuous monitoring with deployed sondes may be beneficial. Utilizing continuous monitoring will help capture the seasonal trends that may have been missed using grab samples (Jones et al. 2011). Due to climate change, storms are occurring less frequently but with higher intensities; thus can stir up sediments. Nutrients are then deposited in the lake in larger amounts during these periods and the ultimately could result in an increase in eutrophication. Stepping up monitoring efforts is imperative to water quality. Newer technology allows samples to be taken more frequently and at set times, using less personnel. Setbacks such as weather will not affect the date and time of the data collection. Results can be analyzed more efficiently allowing for better management of water quality.

CHAPTER VI

CONCLUSION

Skiatook Lake provides not only flood control, but also serves as a water supply to the surrounding region as well as recreation and aesthetics. Water quality is essential to ensure the safety of the people and wildlife that utilize these waters. The analysis of data collected from the years 1994, 2003, and 2004 show a significant increase ($p=0.776$) in TP, no significant change in TKN ($p=0.0001$), and a significant decrease in turbidity ($p=0.77$). However, Secchi readings conclude that the overall clarity of the lake from east to west, along transactional cross-sections demonstrate the dynamics of the lake.

The results of this study show that in 1994 TP decreases from April until November: 0.06 mg/l to 0.04 mg/l. There were 24 samples that fell below the detection limits. In 2003 it decreased from 0.81 mg/l to 0.035 mg/l and 2004 also decreased, 0.06 mg/l to 0.035 mg/l, throughout the year. Over all, the mean of all 3 years increased from 0.0473 mg/l in 1994 to 0.0546 mg/l in 2003 and back down to 0.0422 mg/l in 2004. There was a significant increase in TP. TKN increased throughout the year in 1994 and 2004. On the other hand, 2003 decreased from 0.49 mg/l to 0.37 mg/l. When comparing the 10 difference from 1994 to 2004, the mean decreased from 0.5692 mg/l to 0.4160 mg/l. The statistical results showed there was not a significant change. Turbidity results for all three years decreased from the beginning of the year towards the end. The mean of each individual year came down from 27.93 NTU in 1994 to 20.2747 NTU in 2004. The western portion of Skiatook Lake is very turbid compared with the eastern side. There was a significant decrease from 1994 to 2004. Secchi disk depths increased from the beginning of the year towards the end of the year. In 1994 it increased from 0.6 m to 1.9 m, 2003 increased from 1.75 m to 2.2 m, and in 2004 visibility increased from 0.7 m to 1.7 m. The mean for 1994 was 1.2763 m, in 2003 it was 1.9869 m, and in 2004 the mean was 1.3441 m. Secchi depths are dependent on water stratification and algal growth. The depths usually decrease during algal growth in the spring until it peaks in the summer; then Secchi depths increase again. Skiatook Lake thermally stratifies in the warmer months and mixes again during the winter. The Secchi disk readings correspond with that.

A positive correlation was shown between TP and turbidity. This relationship can be a useful tool for watershed management and allow turbidity values to act as a surrogate for the measurement of TP. Studies conducted by Meozzi concluded that turbidity can act as a surrogate to TP with knowledge of soil characteristics and topography of the area (2011). Using continuous monitoring for turbidity may provide better quality data when used as a surrogate for TP (Kulasova et al. 2012 and Jones et. al 2011).

The findings in this study have indicated some decrease in water quality, whereas some characteristics remain the same. Continued analysis of water quality is vital. Fresh water continues to be a limited resource and is essential for all life. Monitoring and controlling pollution to this limited resource is imperative. Preservation is the key, and can be carried out through water and land management.

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APPENDICES

Appendix 1. Raw Data

Location	Date	TKN mg/l	TP mg/l	Turb NTU
217	4/13/1994	0.7	0.23	22
217	5/4/1994			14
217	5/19/1994	0.42	0.017	9
217	6/1/1994			5.7
217	6/22/1994			5.8
217	7/6/1994	0.4	0.01	38
217	7/28/1994		0.02	490
217	8/18/1994	1.08	0.008	3
217	9/7/1994		0.017	0.4
217	9/28/1994	0.63	0.017	2
217	10/12/1994	0.63	0.017	2.9
217	11/18/1994	0.18	0.3	55
217	8/24/2004	0.44		
217	9/9/2004	0.4	0.054	
217	9/22/2004	0.4		
218	4/13/1994	0.35	0.22	13
218	5/4/1994			9
218	5/19/1994	0.24	0.027	7.2
218	6/1/1994			4.8
218	6/22/1994			2.8
218	6/22/1994			41
218	7/6/1994	0.52	0.003	3.5
218	7/6/1994	0.48	0.01	27
218	7/28/1994		0.02	3
218	7/28/1994		0.02	6.4
218	8/18/1994	0.99		4.1

Location	Date	TKN mg/l	TP mg/l	Turb NTU
218	8/18/1994	0.87		0.76
218	9/7/1994		0.017	0.6
218	9/7/1994		0.03	1.2
218	9/28/1994		0.05	1.4
218	9/28/1994	0.56	0.4	3.5
218	10/12/1994	0.2	0.025	1.8
218	10/12/1994	0.65	0.27	13
218	11/18/1994	0.55	0.01	8
218	11/18/1994	0.4	0.008	46
218	3/26/2003	0.4		4.5
218	3/26/2003	0.5		26.1
218	5/22/2003	0.28		0.5
218	5/22/2003	0.37		19.2
218	6/26/2003	0.31		3.9
218	6/26/2003	0.33		32.6
218	7/23/2003	0.24		1.8
218	7/23/2003	0.41		37.6
218	8/25/2003	0.28		0.2
218	8/25/2003	0.65	0.036	27.5
218	9/24/2003	0.23		
218	9/24/2003	0.95	0.065	
218	10/23/2003	0.28		
218	10/23/2003	0.69		
218	1/21/2004	0.2		
218	1/21/2004	0.62		
218	2/25/2004	0.45		
218	2/25/2004	0.34	0.022	
218	4/22/2004	0.32		11.6
218	5/24/2004	0.4		9.3
218	5/24/2004	0.53	0.022	39.3
218	6/23/2004	0.36		1.6
218	6/23/2004	0.39	0.032	43.6
218	7/21/2004	0.17		0.7
218	7/21/2004	0.27		16
218	8/24/2004	0.39		1.3
218	8/24/2004	0.39		11.6
218	9/9/2004	0.27	0.04	1.4

Location	Date	TKN mg/l	TP mg/l	Turb NTU
218	9/9/2004	0.63	0.031	43.4
218	9/22/2004	0.37		0.8
218	9/22/2004	0.49		4
219	4/13/1994	0.3	0.03	8.5
219	5/4/1994			13
219	5/19/1994	0.28	0.043	14.5
219	6/1/1994			2
219	6/22/1994			4
219	6/22/1994			24
219	7/6/1994	0.68	0.02	3
219	7/6/1994	0.33	0.003	38
219	7/28/1994		0.02	2.5
219	7/28/1994		0.03	4.1
219	8/18/1994	1.08		1.9
219	8/18/1994	0.83		0.4
219	9/7/1994		0.008	0.3
219	9/7/1994		0.008	1
219	9/28/1994	0.15	0.03	1.8
219	9/28/1994	0.5	0.07	82
219	10/12/1994	0.78	0.003	1.2
219	10/12/1994	0.78	0.006	39
219	11/18/1994	0.65	0.008	4
219	3/26/2003	0.43		8.3
219	3/26/2003	0.43		11.1
219	5/22/2003	0.4		2
219	5/22/2003	0.4	0.057	72.5
219	6/26/2003	0.26		3.3
219	6/26/2003	0.19		12.1
219	7/23/2003	0.28		0.8
219	7/23/2003	0.26		12.5
219	8/25/2003	0.34		0.7
219	8/25/2003	0.68	0.059	33
219	9/24/2003	0.31		
219	9/24/2003	0.23		
219	10/23/2003	0.37		
219	10/23/2003	0.45		
219	1/21/2004	0.31		
219	1/21/2004	0.22		

Location	Date	TKN mg/l	TP mg/l	Turb NTU
219	2/25/2004	0.49		
219	2/25/2004	0.39		
219	4/22/2004	0.39		23.7
219	4/22/2004	0.35		37.9
219	4/24/2004	0.39	0.049	
219	4/24/2004	0.44	0.081	
219	5/24/2004	0.49		10.4
219	5/24/2004	0.64	0.052	71.9
219	6/23/2004	0.39		3.6
219	6/23/2004	0.41	0.051	219
219	7/21/2004	0.36		0.6
219	7/21/2004	0.4		25.1
219	8/24/2004	0.33	0.026	1.2
219	8/24/2004	0.51	0.028	21.1
219	9/9/2004	0.36	0.028	1.3
219	9/9/2004	0.74	0.037	14.2
219	9/22/2004	0.41		1.4
219	9/22/2004	0.51	0.026	13
220	4/13/1994	0.31	0.03	66
220	5/19/1994	0.38	0.047	24
220	6/1/1994			8.9
220	6/1/1994			
220	6/22/1994			2.3
220	6/22/1994			91
220	7/6/1994	0.85	0.02	4
220	7/6/1994	0.68	0.003	53
220	7/28/1994		0.03	3.8
220	7/28/1994		0.02	12
220	8/18/1994	0.45		0.38
220	8/18/1994	0.72		0.62
220	9/7/1994		0.008	0.3
220	9/7/1994		0.008	0.4
220	9/28/1994	0.45	0.013	3.4
220	10/12/1994	0.95	0.033	5.9
220	10/12/1994	0.8	0.067	27
220	11/18/1994	0.5	0.008	5
220	3/26/2003	0.72		61.3
220	4/24/2003	0.7	0.148	

Location	Date	TKN mg/l	TP mg/l	Turb NTU
220	5/22/2003	0.56	0.05	34.4
220	6/26/2003	0.34		8.6
220	7/23/2003	0.47		7
220	8/25/2003	0.24		1.2
220	9/24/2003	0.31		
220	10/23/2003	0.39		
220	1/21/2004	0.36		
220	2/25/2004	0.42	0.046	
220	4/22/2004	0.44	0.092	94.2
220	5/24/2004	0.68	0.045	52.3
220	6/23/2004	0.43	0.029	22.4
220	7/21/2004	0.39		3.6
220	8/24/2004	0.4	0.023	2.7
220	8/24/2004	0.44		26.4
220	9/9/2004	0.45	0.032	6.6
220	9/22/2004	0.43		5
220	9/22/2004	0.45		11.4
221	4/13/1994	0.6	0.13	645
221	5/4/1994			76
221	5/19/1994	0.4	0.06	47.5
221	5/19/1994	0.25	0.07	43.5
221	6/1/1994			19
221	6/1/1994			14
221	7/6/1994	0.47	0.02	11
221	7/6/1994	1.05	0.02	
221	7/28/1994		0.03	5.6
221	7/28/1994			25
221	8/18/1994	0.68		0.4
221	8/18/1994	0.63		0.55
221	9/7/1994		0.008	0.6
221	9/7/1994		0.008	8
221	9/28/1994	0.28	0.033	9
221	9/28/1994	0.25	0.023	46
221	10/12/1994	0.58	0.117	14
221	11/18/1994	0.97	0.008	10
221	3/26/2003	1.27		373
221	4/24/2003	0.32	0.03	

Location	Date	TKN mg/l	TP mg/l	Turb NTU
221	5/22/2003	0.66	0.085	109.6
221	6/26/2003	0.52	0.022	42.9
221	7/23/2003	0.48		29.7
221	8/25/2003	0.33		5.6
221	9/24/2003	0.45	0.037	
221	10/23/2003	0.59	0.035	
221	1/21/2004	0.36	0.065	
221	2/25/2004	0.74	0.095	
221	4/22/2004	0.57	0.101	107.1
221	5/24/2004	0.69	0.074	80.2
221	6/23/2004	0.69	0.074	54.3
221	7/21/2004	0.52		7.7
221	8/24/2004	0.51	0.025	11.5
221	8/24/2004	0.61	0.04	41.8
221	9/9/2004	0.55	0.045	13.4
221	9/9/2004	0.47	0.047	41.9
221	9/22/2004	0.55		17.7
263	3/26/2003	0.55		3.7
263	3/26/2003	0.49		14.8
263	5/22/2003	0.4		1
263	5/22/2003	0.43	0.03	37.4
263	6/26/2003	0.31		2
263	6/26/2003	0.29		54.7
263	7/23/2003	0.24		2
263	7/23/2003	0.33		16
263	8/25/2003	0.29		0.4
263	8/25/2003	0.55		8.1
263	9/24/2003	0.43		
263	9/24/2003	0.87	0.035	
263	10/23/2003	0.4		
263	1/21/2004	0.24		
263	1/21/2004	0.39		
263	2/25/2004	0.31	0.029	
263	2/25/2004	0.31	0.033	
263	4/22/2004	0.3		11.7
263	5/24/2004	0.36	0.024	9.2
263	5/24/2004	0.52	0.027	56.2

Location	Date	TKN mg/l	TP mg/l	Turb NTU
263	6/23/2004	0.33	0.021	1.6
263	6/23/2004	0.36	0.033	37.3
263	7/21/2004	0.31		0.9
263	7/21/2004	0.31		15.8
263	8/24/2004	0.36		1.4
263	8/24/2004	0.54		6
263	9/9/2004	0.3	0.033	1.7
263	9/9/2004	0.42	0.038	5.7
263	9/22/2004	0.35		0.6
263	9/22/2004	0.55		4.5
264	3/26/2003	0.4		4.6
264	4/24/2003	0.53	0.109	
264	5/22/2003	0.37		2.1
264	6/26/2003	0.24		2.5
264	7/23/2003	0.24		1.1
264	8/25/2003	0.25		7.7
264	9/24/2003	0.31		
264	10/23/2003	0.45		
264	1/21/2004	0.12	0.022	
264	2/25/2004	0.26	0.038	
264	4/22/2004	0.27		11.4
264	5/24/2004	0.42		9.1
264	6/23/2004	0.27		5.7
264	7/21/2004	0.36		2.3
264	8/24/2004	0.39		6.8
264	9/9/2004	0.35		1.5
264	9/22/2004	0.42		1
267	7/23/2003	0.44	0.021	
267	9/24/2003	0.37		
271	4/22/2004	0.62	0.023	
271	6/23/2004			3.4
271	8/24/2004	0.42		
271	9/9/2004	0.39		4.6
271	9/22/2004	0.07		5.2
272	4/22/2004	0.55	0.041	
272	6/23/2004			3
272	8/24/2004	0.48		
272	9/9/2004	0.37		2.3
272	9/22/2004	0.41		1.4

Appendix 2. Descriptive statistics for total phosphorus (mg/l) on Skiatook Lake for the 1994, 2003, and 2004 sampling period.

Site #	Year	Min.	Max.	Mean	Median	# Samples	# of Obs. BDL[l]
217	1994	0.01	0.30	0.07067	0.1585	9	6
	2004	0.05	0.05	0.05400	0.0540	1	0
218	1994	0.00	0.40	0.07929	0.0225	14	5
	2003	0.04	0.07	0.05050	0.0505	2	0
	2004	0.02	0.04	0.02940	0.0310	5	0
219	1994	0.00	0.07	0.02146	0.0200	13	6
	2003	0.06	0.06	0.05800	0.0580	2	0
	2004	0.03	0.08	0.04200	0.0370	9	0
220	1994	0.00	0.07	0.02392	0.0200	12	4
	2003	0.05	0.15	0.09900	0.0990	2	0
	2004	0.02	0.09	0.04450	0.0385	6	0
221	1994	0.01	0.13	0.04392	0.0265	12	3
	2003	0.02	0.09	0.04180	0.0350	5	0
	2004	0.03	0.10	0.06289	0.0650	9	0
263	2003	0.03	0.04	0.03250	0.0325	2	0
	2004	0.02	0.04	0.02975	0.0310	8	0
264	2003	0.11	0.11	0.10900	0.1090	1	0
	2004	0.22	0.38	0.03000	0.0300	2	0
267	2003	0.02	0.02	0.02100	0.0210	1	0
271	2004	0.02	0.02	0.02300	0.0230	1	0
272	2004	0.04	0.04	0.04100	0.0410	1	0

[l]BDL=Below Detection Limit

Appendix 3. Descriptive statistics for total Kjeldahl nitrogen (mg/l) on Skiatook Lake for the 1994, 2003, and 2004 sampling period.

Site #	Year	Min.	Max.	Mean	Median	# Samples	# of Obs. BDL[1]
217	1994	0.18	1.08	0.57714	0.6300	7	0
	2004	0.40	0.44	0.41333	0.4000	3	0
218	1994	0.20	0.99	0.52818	0.5200	20	0
	2003	0.23	0.95	0.42286	0.3500	14	0
	2004	0.17	0.63	0.38765	0.3900	17	0
219	1994	0.15	1.08	0.57818	0.6500	11	0
	2003	0.19	0.68	0.35929	0.3550	14	0
	2004	0.22	0.74	0.42650	0.3950	19	0
220	1994	0.31	0.95	0.60900	0.5900	10	0
	2003	0.24	0.72	0.46625	0.4300	8	0
	2004	0.36	0.68	0.44455	0.4300	11	0
221	1994	0.25	1.05	0.56000	0.5800	11	0
	2003	0.32	1.27	0.57750	0.5000	8	0
	2004	0.36	0.74	0.56909	0.5500	11	0
263	2003	0.24	0.87	0.42923	0.4000	13	0
	2004	0.24	0.55	0.36824	0.3500	17	0
264	2003	0.24	0.53	0.34875	0.3400	8	0
	2004	0.12	0.42	0.31778	0.3500	9	0
267	2003	0.37	0.44	0.40500	0.4050	2	0
271	2004	0.07	0.62	0.37500	0.4050	4	0
272	2004	0.37	0.55	0.45250	0.4450	4	0

[1]BDL= Below Detection Limit

Appendix 4. Descriptive statistics for turbidity (NTU) on Skiatook Lake for the 1994, 2003, and 2004 sampling period.

Site #	Year	Min.	Max.	Mean	Median	# Samples
217	1994	0.40	490.00	53.98333	7.4000	12
	2004	n/a	n/a	n/a	n/a	0
218	1994	0.60	46.00	9.90300	4.4500	20
	2003	0.20	37.60	153.90000	0.6900	10
	2004	0.70	43.60	14.20000	9.3000	13
219	1994	0.30	82.00	12.90530	4.0000	19
	2003	0.70	72.50	15.63000	9.7000	10
	2004	0.60	219.00	31.74290	13.6000	14
220	1994	0.30	91.00	18.11760	5.0000	17
	2003	1.20	61.30	22.50000	8.6000	5
	2004	2.70	94.20	24.95560	11.4000	9
221	1994	0.40	645.00	57.36180	14.0000	17
	2003	5.60	373.00	112.16000	42.9000	5
	2004	7.70	107.10	41.73330	41.8000	9
263	2003	0.40	54.70	14.01000	5.9000	10
	2004	0.60	56.20	11.73850	5.7000	13
264	2003	1.10	7.70	3.60000	2.5000	5
	2004	1.00	11.40	5.40000	5.7000	7
267	2003	n/a	n/a	n/a	n/a	0
271	2004	3.40	5.20	4.40000	4.6000	3
272	2004	1.40	3.00	2.23333	2.3000	3

Appendix 5. Descriptive statistics for Secchi disk (m) on Skiatook Lake for the 1994, 2003, and 2004 sampling period.

Site #	Year	Min.	Max.	Mean	Median	# Sample
218	1994	0.55	3.50	1.8450	1.70	10
	2003	2.50	3.18	2.7450	2.65	4
	2004	0.70	3.05	1.7700	1.70	9
219	1994	0.40	3.50	1.7900	2.00	10
	2003	2.20	3.00	2.5200	2.40	5
220	1994	0.20	1.60	0.9500	1.00	8
	2003	0.90	1.80	1.1840	0.92	5
	2004	0.13	1.46	0.7720	0.80	9
221	1994	0.10	0.80	0.4550	0.50	10
	2003	0.18	11.00	0.4840	0.30	5
	2004	0.13	0.86	0.3933	0.27	9
263	2003	2.43	3.42	2.7900	2.80	5
	2004	0.90	3.10	1.7267	1.65	9
264	2003	1.70	3.50	2.3500	1.95	5
	2004	0.65	2.40	1.4500	1.22	9
271	2004	1.00	2.20	1.7200	1.96	3
272	2004	1.58	2.05	1.7930	1.75	3

Appendix 6. Descriptive statistics for chlorophyll a (ug/l) on Skiatook Lake for the 1994, 2003, and 2004 sampling period.

Site #	Year	Min.	Max.	Mean	Median	# Samples
217	1994	n/a	n/a	n/a	n/a	0
	2004	3.7	4.8	4.25	4.25	2
218	1994	n/a	n/a	n/a	n/a	0
	2003	1.4	4.5	3.05714286	3.3	7
	2004	1.3	10.1	4.6	4.1	9
219	1994	n/a	n/a	n/a	n/a	0
	2003	1.7	4.1	3.3	3.5	7
	2004	1.3	10.3	4.72	4.05	10
220	1994	n/a	n/a	n/a	n/a	0
	2003	2.6	14.5	6.15	5.3	8
	2004	1.6	10.6	6.35556	6.1	9
221	1994	n/a	n/a	n/a	n/a	0
	2003	1.2	12.8	6.2125	5.2	8
	2004	0.7	11.7	6.43333	6.6	9
263	2003	1	3.6	2.52857	2.6	7
	2004	1.8	10.8	4.7	3.9	9
264	2003	1.1	3.3	2.37143	2.5	7
	2004	0.8	9.7	4.21111	3.6	9
267	2003	5.2	5.3	5.25	5.25	2
271	2004	n/a	n/a	n/a	n/a	0
272	2004	n/a	n/a	n/a	n/a	0

VITA

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Pages in Study: 60 Candidate for the Degree of Master of Science

Major Field: Environmental Science

Scope and Method of Study: Skiatook Lake, located in Osage County, Oklahoma, was impounded in 1984. Its main purposes were to provide water supply, flood control, and fish and wildlife habitat. It also provides for many recreational activities for the public. Anthropogenic and non-anthropogenic activities can cause an increase in nutrients entering surface water over time. This paper analyzed any change in concentrations that occurred, also accounted for no change that occurred in Skiatook Lake between the years 1993 and 2003-2004. The water quality parameters used were total phosphorus, total Kjeldahl nitrogen, turbidity, and Secchi depths. Data for the project was provided by the U.S. Army Corps of Engineer. A positive correlation was established for total phosphorus and turbidity in the given sampling period. Data was combined for all 3 years and each parameter was analyzed using an analysis of variance (ANOVA). The significance was measured at α=0.05.

Findings and Conclusions: The analysis of data collected from the years 1994, 2003, and 2004 show a significant increase (p=0.776) in TP, no significant change in TKN (p=0.0001), and a significant increase in turbidity (p=0.77). However, Secchi readings conclude that the overall clarity of the lake from east to west, along transactional cross-sections demonstrate the dynamics of the lake. Grab sampling efforts are random and may miss important collection periods. There can be holes in the data, creating potential bias. Benefits for using continuous monitoring year round are widespread. Seasonal trends may be more easily detected, effects of rainfall events are captured, and fewer personnel are needed. Best management practices can be implemented if needed in response to any water quality shifts. The findings in this study have indicated some decrease in water quality, whereas some characteristics remain the same. Continued analysis of water quality is vital. Additional analysis of individual sites will be very beneficial.

ADVISER’S APPROVAL: Dr. Tony Clyde